



# Ambient Water Quality Criteria Recommendations

**Information Supporting the Development  
of State and Tribal Nutrient Criteria**

## Lakes and Reservoirs in Nutrient Ecoregion I





**AMBIENT WATER QUALITY CRITERIA RECOMMENDATIONS**

**INFORMATION SUPPORTING THE DEVELOPMENT OF STATE AND TRIBAL  
NUTRIENT CRITERIA**

**FOR**

**LAKES AND RESERVOIRS IN NUTRIENT ECOREGION I**

*Willamette and Central Valleys*

*including all or parts of the States of:*

*Washington, Oregon, and California,*

*and the authorized Tribes within the Ecoregion*

**U.S. ENVIRONMENTAL PROTECTION AGENCY**

**OFFICE OF WATER  
OFFICE OF SCIENCE AND TECHNOLOGY  
HEALTH AND ECOLOGICAL CRITERIA DIVISION  
WASHINGTON, DC**

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## FOREWORD

This document presents EPA's nutrient criteria for **Lakes and Reservoirs in Nutrient Ecoregion I**. These criteria provide EPA's recommendations to States and authorized Tribes for use in establishing their water quality standards consistent with section 303(c) of the Clean Water Act (CWA). Under section 303(c) of the CWA, States and authorized Tribes have the primary responsibility for adopting water quality standards as part of State or Tribal law or regulation. Federal regulations require State and Tribal standards to contain scientifically defensible water quality criteria that are protective of designated uses. EPA's recommended section 304(a) criteria are not laws or regulations; they are guidance that States and Tribes may use as a starting point in creating their own water quality standards.

The term "water quality criteria" is used in two sections of the CWA, section 304(a)(1) and section 303(c)(2). The term has a different impact in each section. On the one hand, in section 304, the term represents a scientific assessment of ecological and human health effects that EPA recommends to States and authorized Tribes for establishing water quality standards that ultimately provide a basis for controlling discharges or releases of pollutants or related parameters. On the other hand, in section 303, ambient water quality criteria are developed by States and Tribes as part of their water quality standards, to define the level of a pollutant (or in the case of nutrients, a condition) necessary to protect designated uses in ambient waters.

Quantified water quality criteria contained within State or Tribal water quality standards are essential to a water quality-based approach to pollution control. Whether expressed numerically or as quantified translations of narrative criteria within State or Tribal water quality standards, quantified criteria are critical for assessing attainment of designated uses and measuring progress toward meeting CWA goals.

EPA is developing section 304(a) water quality criteria for nutrients because States and Tribes consistently identify excessive levels of nutrients as a major reason that as many as half of the Nation's surface waters surveyed do not meet water quality objectives, such as full support of aquatic life. EPA expects to develop nutrient criteria that cover four major types of waterbodies—lakes and reservoirs, rivers and streams, estuarine and coastal areas, and wetlands—across 14 major ecoregions of the United States. EPA's section 304(a) criteria are intended to provide for the protection and propagation of aquatic life and recreation. To support the development of nutrient criteria, EPA has published and will continue to publish technical guidance manuals that describe a process for assessing nutrient conditions in the four waterbody types listed above.

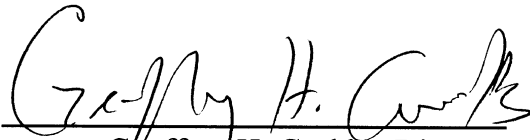
EPA's section 304(a) water quality criteria for nutrients provide numeric water quality criteria and procedures to help establish quantified criteria within State or Tribal water quality standards. In the case of nutrients, EPA section 304(a) criteria establish values for causal variables (e.g., total nitrogen and total phosphorus) and response variables (e.g., Secchi depth and chlorophyll *a*). EPA believes that State and Tribal water quality standards need to include quantified endpoints for causal and response variables to provide sufficient protection of uses and to maintain downstream uses. These endpoints will most often be expressed as numeric

water quality criteria or as procedures to translate a State or Tribal narrative criterion into a quantified endpoint.

States and authorized Tribes have several options in adopting these criteria. EPA recommends the following approaches, in order of preference:

1. Wherever possible, develop nutrient criteria that fully reflect local conditions and protect specific designated uses through the process described in EPA's technical guidance manuals for nutrient criteria development. Such criteria may be expressed either as numeric criteria or as procedures to translate a State or Tribal narrative criterion into a quantified endpoint in State or Tribal water quality standards.
2. Adopt EPA's section 304(a) water quality criteria for nutrients, either as numeric criteria or as procedures to translate a State or Tribal narrative nutrient criterion into a quantified endpoint.
3. Develop nutrient criteria protective of designated uses using other scientifically defensible methods and appropriate water quality data.

EPA developed the nutrient criteria recommendations in this document with the intent that they serve as a starting point for States and Tribes to develop more refined criteria, as appropriate, to reflect local conditions. The values presented in this document generally represent nutrient levels that protect against the adverse effects of nutrient overenrichment. They are based on the information that was available to the Agency at the time of this publication. EPA expects States and Tribes may have additional information and data that may be utilized in the refinement of these criteria. EPA offers to work with States and authorized Tribes to establish the necessary quantitative endpoints to reduce the excess nutrient inputs into our nation's waters and to prevent any further impairments.



Geoffrey H. Grubbs, Director  
Office of Science and Technology

## **DISCLAIMER**

This document provides technical guidance and recommendations to States, authorized Tribes, and other authorized jurisdictions to develop water quality criteria and water quality standards under the Clean Water Act (CWA) to protect against the adverse effects of nutrient overenrichment. Under the CWA, States and authorized Tribes are to establish water quality criteria to protect designated uses. State and Tribal decisionmakers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance when appropriate and scientifically defensible. Even though this document contains EPA's scientific recommendations regarding ambient concentrations of nutrients that will protect aquatic resource quality, it does not substitute for the CWA or EPA regulations, nor is it a regulation itself. Thus it cannot impose legally binding requirements on EPA, States, authorized Tribes, or the regulated community, and it might not apply to a particular situation or circumstance. EPA may change this guidance in the future.





## EXECUTIVE SUMMARY

### Nutrient Program Goals

EPA developed the National Strategy for the Development of Regional Nutrient Criteria (National Strategy) in June 1998. The strategy presents EPA's intentions to develop technical guidance manuals for four types of waters (lakes and reservoirs, rivers and streams, estuaries and coastal waters, and wetlands) and produce section 304(a) criteria for specific nutrient Ecoregions by the end of 2000. In addition, the Agency formed Regional Technical Assistance Groups (RTAGs), which include State and Tribal representatives working to develop more refined and localized nutrient criteria based on approaches described in the waterbody guidance manuals. This document presents EPA's current recommended criteria for total phosphorus (TP), total nitrogen (TN), chlorophyll *a*, and Secchi for lakes and reservoirs in Nutrient Ecoregion I, which were derived using the procedures described in the *Lakes and Reservoirs Nutrient Criteria Technical Guidance Manual* (U.S. EPA, 2000a). The data for this document comes from subecoregion 3, and is based on 8 lakes out of a population totaling approximately 245 (lakes > 4 hectares).

EPA's ecoregional nutrient criteria address cultural eutrophication—the adverse effects of excess human-caused nutrient inputs. The criteria are empirically derived to represent surface waters that are minimally impacted by human activities and protective of aquatic life and recreational uses. The information contained in this document represents starting points for States and Tribes to develop (with assistance from EPA) more refined nutrient criteria.

In developing these criteria recommendations, EPA followed a process that included, to the extent they were readily available, the following critical elements:

- **Historical and recent nutrient data in Nutrient Ecoregion I.** Data sets from Legacy STORET, and EPA Region 10.
- **Reference sites/reference conditions in Nutrient Ecoregion I.** Reference conditions presented are based on 25th percentiles of all nutrient data, including a comparison of reference conditions for the Aggregate Ecoregion versus the subcoregions. States and Tribes are urged to determine their own reference sites for lakes and reservoirs at different geographic scales and to compare them to EPA's reference conditions.
- **Models employed for prediction or validation.** EPA did not identify any specific models to develop nutrient criteria. States and Tribes are encouraged to identify and apply appropriate models to support nutrient criteria development.
- **RTAG expert review and consensus.** EPA recommends that when States and Tribes prepare their nutrient criteria, they obtain the expert review and consent of the RTAG.
- **Downstream effects of criteria.** EPA encourages the RTAG to assess the potential effects of the proposed criteria on downstream water quality and uses.

In addition, EPA followed specific **QA/QC procedures** during data collection and analysis. All data were reviewed for duplications. All data were from ambient waters that were not located directly outside a permitted discharger. The following States indicated standard methods or approved EPA methods were used: Washington and Oregon.

The following table contains a summary of Aggregate and level III Ecoregion values for TN, TP, water column chlorophyll *a*, and Secchi. Since all of the data for the Aggregate Ecoregion is from subcoregion 3 (the Willamette Valley in Oregon), the subcoregion and Aggregate Ecoregion data is presented in one table.

**BASED ON 25th PERCENTILES ONLY**

<b>Nutrient Parameters</b>	<b>Aggregate Nutrient Ecoregion I (and subcoregion 3) Reference Conditions</b>
Total phosphorus (µg/L)	55
Total nitrogen (mg/L) (calculated)	0.66
Chlorophyll <i>a</i> (µg/L) (flourometric method)	4.88
Secchi (m)	2.55

**Note:** Values in this table are based on data from 12 stations, in 8 lakes (of 245) in subcoregion 3.

## **NOTICE OF DOCUMENT AVAILABILITY**

This document is available electronically to the public through the Internet at <http://www.epa.gov/OST/standards/nutrient.html>. Requests for hard copies of the document should be made to EPA's National Service Center for Environmental Publications (NSCEP), 11029 Kenwood Road, Cincinnati, OH 45242; telephone (513) 489-8190 or toll free (800) 490-9198. Please refer to EPA document number EPA-22-R-02-050.

## **ACKNOWLEDGMENTS**

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## 1.0 INTRODUCTION

### Background

Nutrients are essential to the health and diversity of surface waters. However, in excessive amounts nutrients cause eutrophication or hypereutrophication, which results in overgrowth of plant life and decline of the biological community. Excessive nutrients can also result in human health risks, such as the growth of harmful algal blooms. Chronic nutrient overenrichment of a waterbody can lead to the following consequences: algal blooms, low dissolved oxygen, fish kills, overabundance of macrophytes, increased sedimentation, and species shifts of both flora and fauna.

Historically, National Water Quality Inventories have repeatedly shown that nutrients are a major cause of ambient water quality use impairments. EPA's 1996 National Water Quality Inventory report identifies excessive nutrients as the leading cause of impairment in lakes and the second leading cause of impairment in rivers (behind siltation). In addition, nutrients were the second leading cause of impairments after siltation reported by the States in their 1998 lists of impaired waters. Where use impairment is documented, nutrients contribute roughly 25%-50% of the impairment nationally. The Clean Water Act (CWA) establishes that, wherever possible, water quality must provide for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water and/or protecting the physical, chemical, and biological integrity of those waters. In adopting water quality standards, States and Tribes designate uses for their waters in consideration of these CWA goals, and establish water quality criteria that contain sufficient parameters to protect that integrity and those uses. To date, EPA has not published information and recommendations under section 304(a) for nutrients to assist States and Tribes in establishing numeric nutrient criteria to protect uses when adopting water quality standards.

In 1995, EPA gathered a set of national experts and asked them how best to deal with the national nutrient problem. The experts recommended that the Agency not develop single criteria values for phosphorus (P) or nitrogen (N) applicable to all waterbodies and regions of the country. Rather, they recommended that EPA put a premium on regionalization, develop guidance (assessment tools and control measures) for specific waterbodies and ecological regions across the country, and use reference conditions (conditions that reflect pristine or minimally impacted waters) as a basis for developing nutrient criteria.

With these suggestions as starting points, EPA developed the National Strategy for the Development of Regional Nutrient Criteria (National Strategy), published in June 1998. This strategy presented EPA's intentions to develop technical guidance manuals for four types of waters (lakes and reservoirs, rivers and streams, estuaries and coastal waters, and wetlands), and thereafter to publish section 304(a) criteria recommendations for specific nutrient Ecoregions. Technical guidance manuals for lakes/reservoirs and rivers/streams were published in April 2000 and July 2000, respectively. The technical guidance manual for estuaries/coastal waters was published in fall 2001, and the draft wetlands technical guidance manual will be published by December 2001. Each manual presents EPA's recommended approach for developing nutrient criteria values for a specific waterbody type. In addition, EPA is committed to working with

States and Tribes to develop more refined and localized nutrient criteria based on approaches described in the waterbody guidance manuals and this document.

## **Overview of the Nutrient Criteria Development Process**

For each nutrient Ecoregion, EPA developed a set of recommendations for two causal variables (total nitrogen and total phosphorus) and two early indicator response variables (chlorophyll *a* [chl *a*] and Secchi). Other indicators such as dissolved oxygen, macrophyte or benthic algal growth or speciation, and other fauna and flora changes are also useful. However, the first four variables are considered to be the best suited for protecting designated uses.

The technical guidance manuals describe a process for developing nutrient criteria that involves consideration of five factors. The first of these is the Regional Technical Assistance Group (RTAG), which is a body of qualified regional specialists able to objectively evaluate all of the available evidence and select the value(s) appropriate to nutrient control in the water bodies of concern. These specialists may come from such disciplines as limnology, biology, or natural resources management—especially water resource management, chemistry, and ecology. The RTAG evaluates and recommends appropriate classification techniques, usually physical, for criteria determination within an ecoregional construct.

The second factor is the historical information available to establish a perspective of the resource base. This is usually data and anecdotal information available within the past 10-25 years. This information gives evidence about the background and enrichment trend of the resource.

The third factor is the existing reference condition, a selection of reference sites chosen to represent the least culturally impacted waters of the class at the present time. The data from these sites are combined and a value is selected to represent the reference condition, the best attainable, most natural condition of the resource base at this time.

The RTAG comprehensively evaluates these three elements to propose a candidate criterion (initially one each for TP, TN, chl *a*, and Secchi).

A fourth factor often employed is mechanistic or empirical models of the historical and reference condition data to better understand the condition of the resource.

The final element of the process is assessment by the RTAG of the likely downstream effects of the criterion. Will there be a negative, positive, or neutral effect on the downstream waterbody? If the RTAG judges that a negative effect is likely, then the proposed State/Tribal water quality criteria should be revised to ameliorate the potential for any adverse downstream effects.

Although States and authorized Tribes do not necessarily need to incorporate all five elements into their water quality criteria setting process (e.g., modeling may be significant in only some instances), the best assurance of a representative and effective criterion is a balanced incorporation of all five elements.

Because some parts of the country have naturally different soil and parent material nutrient content, and different precipitation regimes, the application of the criterion development process should reflect this regional variation. Therefore, an ecoregional approach was chosen. Initially, the continental United States was divided into 14 separate Ecoregions of similar geographical characteristics and similar nutrient condition (Figure 1a). Ecoregions are defined as regions of relative homogeneity in ecological systems; they depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) is different from adjacent areas in a holistic sense. Geographic characteristics such as soils, vegetation, climate, geology, and land cover are relatively similar within each Ecoregion (Omernik, 2000).

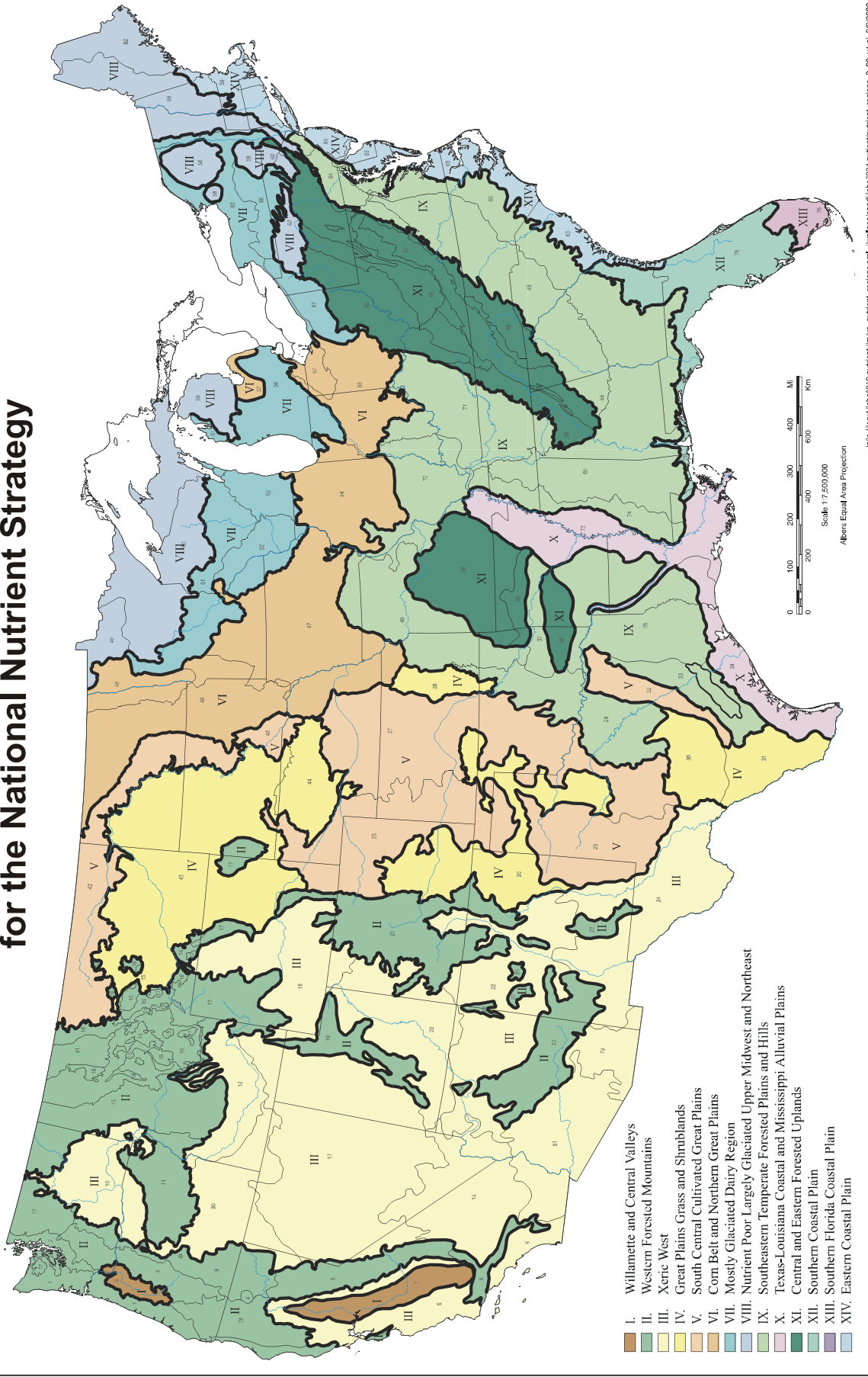
The nutrient Ecoregions are aggregates of EPA's hierarchical level III Ecoregions (see Figure 1b for a map of level III Ecoregions). As such, they are more generalized and less defined than level III Ecoregions. EPA determined that setting ecoregional criteria for the large-scale aggregates is not without its drawbacks: variability is high because of the lumping of many waterbody classes, seasons, and years worth of multipurpose data over a large geographic area. For these reasons, the Agency recommends that States and Tribes develop nutrient criteria at the level III ecoregional scale and at the waterbody-class scale, where those data are readily available. Data analyses and recommendations on both the large Aggregate Ecoregion scale and the more refined scales (level III Ecoregions and waterbody classes), where data were available to make such assessments, are presented for comparison and completeness of analysis.

### **Comparison of Nutrient Criteria to Biological Criteria**

Biological criteria are quantitative expressions of the desired condition of the aquatic community. Such criteria can be based on data from sites that represent the least impacted attainable condition for a particular waterbody type in an Ecoregion, subecoregion, or watershed. EPA's nutrient criteria recommendations and biological criteria recommendations have many similarities in their basic approaches to development and data requirements. Both are empirically derived from statistical analysis of field-collected data and expert evaluation of current reference conditions and historical information. Both use direct measurements from the environment to integrate the effects of complex processes that vary according to type and location of waterbody. The resulting criteria recommendations, in both cases, are efficient uses of existing resources and are holistic indicators of the water quality necessary to protect uses.

States and authorized Tribes can develop and apply nutrient and biological criteria in tandem, with each providing important and useful information to interpret both the nutrient enrichment levels and the biological condition of sampled waterbodies. For example, using the same reference sites for both types of criteria can lead to efficiencies in both sample design and data analysis. In one effort, environmental managers can obtain information to support assessment of biological and nutrient condition, either through evaluating existing data sets or through designing and conducting a common sampling program. The traditional biological criteria variables of benthic invertebrate and fish sampling can be readily incorporated in a nutrient assessment. To investigate the effectiveness of this tandem approach, EPA has initiated pilot projects in both freshwater and marine environments to pursue the relationship between nutrient overenrichment and apparent declines in diversity of benthic invertebrates and fish.

# Draft Aggregations of Level III Ecoregions for the National Nutrient Strategy



**Figure 1a. Fourteen nutrient Ecoregions as delineated by Omernik (2000). Ecoregions were based on geology, land use, ecosystem type, and nutrient conditions.**



# Level III Ecoregions of the United States

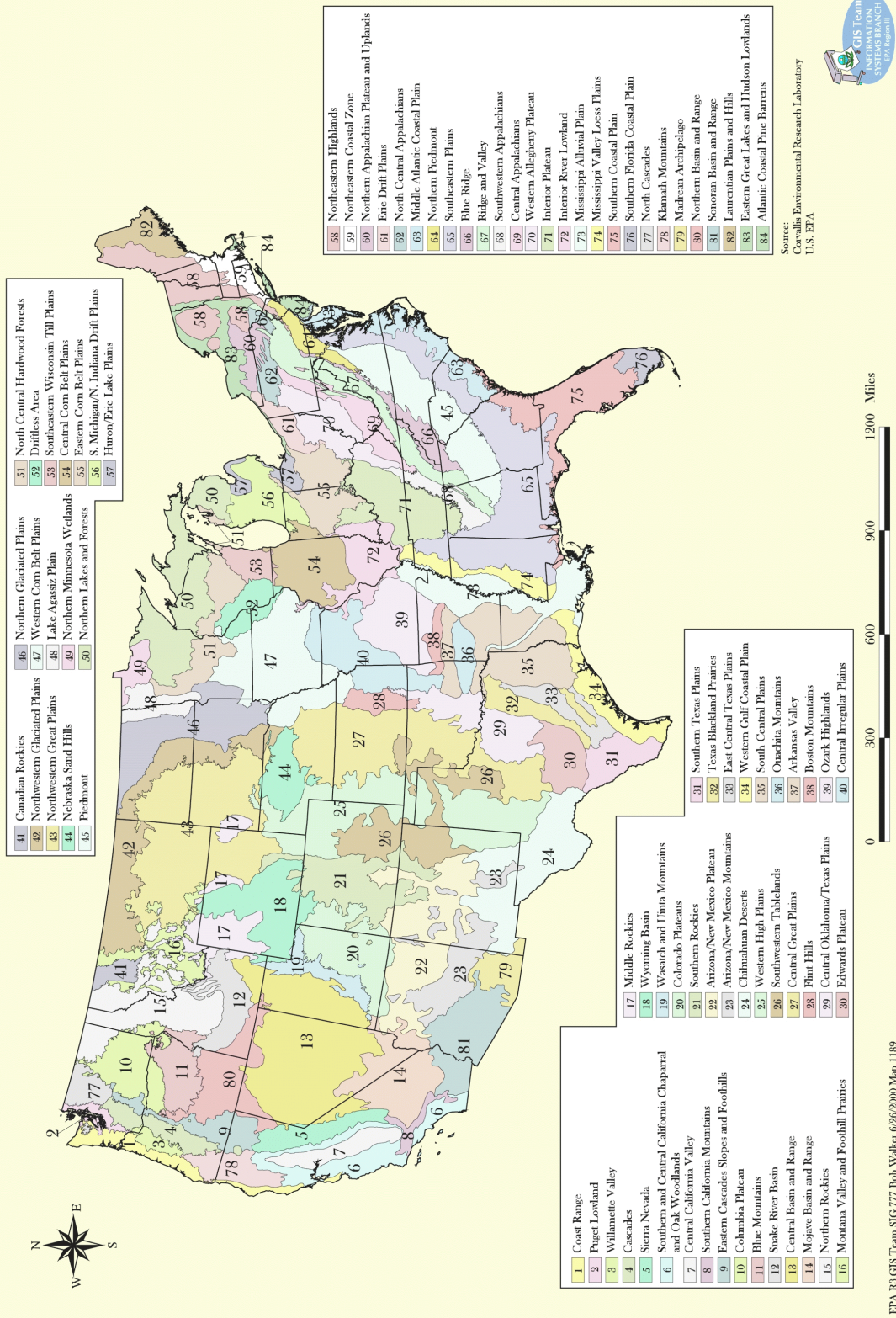


Figure 1b. Level III Ecoregions of the United States.

## 2.0 BEST USE OF THIS INFORMATION

EPA recommendations published under section 304(a) of the CWA serve several purposes, including providing guidance to States and Tribes in adopting water quality standards for nutrients and ultimately controlling discharges or releases of pollutants. The recommendations also provide guidance to EPA when it determines that it is necessary to promulgate Federal water quality standards under section 303(c). Other uses include identification of overenrichment problems, management planning, project evaluation, and determination of status and trends of water resources.

State water quality inventories and listings of impaired waters consistently rank nutrient overenrichment as a top contributor to use impairments. EPA's water quality standards regulations at 40 CFR §131.11(a) require States and Tribes to adopt criteria that contain sufficient parameters and constituents to protect the designated uses of their waters. In addition, States and Tribes need quantifiable targets for nutrients to assess attainment of uses, develop water quality-based permit limits and source control plans, and establish targets for total maximum daily loads (TMDLs).

EPA expects States and Tribes to address nutrient overenrichment in their water quality standards and to build on existing State and Tribal efforts where possible. States and Tribes can address nutrient overenrichment through establishment of numerical criteria or use of narrative criteria statements (e.g., "free from excess nutrients that cause or contribute to undesirable or nuisance aquatic life or produce adverse physiological response in humans, animals, or plants"). In the case of narrative criteria, EPA expects that States and Tribes will establish procedures to quantitatively translate these statements for both assessment and source control purposes.

Ecoregional nutrient criteria are developed to represent surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient overenrichment from cultural eutrophication. EPA's recommended process for developing such criteria includes physical classification of waterbodies, determination of current reference conditions, evaluation of historical data and other information (such as published literature), use of models to simulate physical and ecological processes or determine empirical relationships among causal and response variables (if necessary), expert judgment, and evaluation of downstream effects. EPA has used elements of this process to produce the information contained in this document. The causal (total nitrogen, total phosphorus) and biological and physical response (chlorophyll *a*, Secchi) variables represent a set of starting points for States and Tribes to use in establishing their own criteria.

EPA recommends that States and Tribes establish numerical criteria based on section 304(a) guidance, section 304(a) guidance modified to reflect site-specific conditions, or other scientifically defensible methods. For many pollutants, such as toxic chemicals, EPA expects that section 304(a) guidance will provide an appropriate level of protection without further modification. EPA has also published methods for modifying 304(a) criteria, such as the water effect ratio, on a site-specific basis where conditions warrant modification to achieve the intended level of protection. For nutrients, however, EPA expects that it will usually be necessary for States and authorized Tribes to be more precise in identifying the nutrient levels that protect aquatic life and recreational uses. This can be achieved through criteria modified to

reflect a smaller geographic scale than an Ecoregion, such as a subecoregion, the State or Tribe level, or a specific class of waterbodies. Criteria can be refined by grouping data or performing analyses at these smaller geographic scales. Refinement can also occur through further consideration of other elements such as published literature or models.

EPA expects that the values presented in this document generally represent nutrient levels that protect against the adverse effects of cultural overenrichment and are based on information available to the Agency at the time of this publication. However, States and Tribes should critically evaluate this information in light of the specific uses that need to be protected. For example, more sensitive uses may require more stringent criteria to ensure adequate protection. On the other hand, overly stringent levels of protection against cultural eutrophication may actually fall below the natural load of nutrients for certain waterbodies. In cases such as these, the level of nutrients specified may not be sufficient to support a productive fishery. In the criteria derivation process, it is important to distinguish between the natural load associated with a specific waterbody using historical data and expert judgment and current reference conditions. These elements of the criteria derivation process are best addressed by States and Tribes with access to information and local expertise. Therefore, EPA strongly encourages States and Tribes to use the information contained in this document to develop more refined criteria according to the methods described in EPA's technical guidance manuals for specific waterbody types.

To assist in further refinement of nutrient criteria, EPA has established 10 RTAGs (experts from EPA Regional Offices and States/Tribes). In refining criteria, States and authorized Tribes need to provide documentation of data and analyses, along with a defensible rationale, for any new or revised nutrient criteria they submit to EPA for review and approval. As part of EPA's review of State and Tribal standards, EPA intends to seek assurance from the RTAG that proposed criteria are sufficient to protect uses.

In using the information and recommendations in this document and elsewhere to develop numerical criteria or procedures to translate narrative criteria, EPA encourages States and Tribes to:

- Address both chemical causal variables and early indicator response variables. Causal variables are necessary to protect uses before impairment occurs and to maintain downstream uses. Early response variables are necessary to warn of possible impairment and to integrate the effects of variable and potentially unmeasured nutrient loads.
- Include variables that can be measured to determine if standards are met, and variables that can be related to the ultimate sources of excess nutrients.
- Identify appropriate periods of duration (how long) and frequency (how often) of occurrence in addition to magnitude (how much). EPA does not recommend identifying nutrient concentrations that must be met at all times; rather a seasonal or annual averaging period (e.g., based on weekly or biweekly measurements) is considered appropriate. However, these central tendency measures should apply each season or each year, except under the most extraordinary conditions (e.g., a 100-year flood).

### **3.0 AREA COVERED BY THIS DOCUMENT**

This chapter provides a general description of the Aggregate Ecoregion and its geographical boundaries. Descriptions of the level III subcoregions contained within the Aggregate Ecoregion are also provided.

#### **3.1 Description of Aggregate Ecoregion I**

Ecoregion I is composed of broad, arable, western valleys that are drier, flatter, and much more densely populated than the neighboring Western Forested Mountains (II). This ecoregion encompasses two river valley areas, the Willamette Valley in Oregon and Washington and the Central Valley in California. Soils are typically nutrient-rich and more naturally fertile than those of the adjacent nutrient regions. They support mostly cropland agriculture. Erosion, fertilizer use, irrigation return, livestock, urbanization, and industrialization have degraded the surficial water quality of the region by increasing levels of nutrients, dissolved solids, toxic compounds, and fecal coliform bacteria.

The broad, Willamette Valley is composed of nearly level terraces and floodplains that are interlaced and surrounded by rolling hills. The meandering, low gradient Willamette River and its tributaries drain the Valley and have formed oxbow lakes. Elevations range from 10 to 1,500 feet. The mean annual precipitation varies from 37 to 60 inches and the average freeze-free season is 165-210 days. The potential natural vegetation includes Douglas-fir-hemlock-cedar forests and Oregon oakwoods; in addition, wetlands, Oregon white oak savanna, prairies, riparian forests of cottonwoods and willows were part of the pre-settlement landscape. Today, the Willamette Valley is the most important agricultural area in Oregon. Cropland agriculture is widespread and contrasts with the prevailing land use of the Western Forested Mountains (II). The Willamette Valley's climate is ocean influenced and mild. Precipitation is concentrated in the fall, winter, and spring months; summers are dry and, correspondingly, summer streamflow is relatively low. The Valley's temperate climate and its productive, nutrient-rich soils support an especially wide range of crops including grass seed vegetables, berries, wine grapes, nursery stock, Christmas trees, hay, and grain; pastureland is also common. The Valley's moderate precipitation and plentiful streamflow furnish enough water for present needs; additional supplies are available from adjoining mountain ranges. The Willamette Valley is the home to most of Oregon's rapidly growing population and industrial base. Urbanization, fertilizer use, industrialization, irrigation return, nearby logging, and livestock have affected surficial water quality. Dissolved phosphorus in some streams is rising due to human activities including agricultural use of phosphorus fertilizer, greater runoff from suburban-urban areas, and more discharge from municipal sewage treatment plants. Dissolved oxygen is decreasing in some streams within suburbanized and urbanized watersheds.

The Central Valley of California is composed of the intensively farmed Sacramento and San Joaquin valleys. Elevations range from 0 to 650 feet. The mean annual precipitation varies from 5 to 25 inches and the average freeze-free season is 230 to 350 days. The potential natural vegetation of the Central Valley includes California steppe, tule marshes, and salt bush-greasewood; oak, willow, and cottonwood naturally occurred along streams and salt bush originally grew on saline sodic soils. The land use mosaic, potential natural vegetation, and terrain are all different in the nearby Western Forested Mountains (II) and Xeric West (III).



Long, hot, dry summers and cool, rainy winters are characteristic of the Central Valley. Stream flow is limited over much of the area during the summer and water for crops often comes from stream diversions, wells, canals, and reservoirs. More than 90% of the Central Valley is in farms and ranches; urban or suburban areas have been rapidly expanding but occupy less than 5% of the Central Valley. Nearly half of the region is in cropland, about three fourths of which is irrigated. Environmental concerns in the region include high concentrations of salt and toxic chemicals in drainage waters, high phosphorus and nitrogen concentrations in streams from nonpoint sources, groundwater contamination from heavy use of agricultural chemicals, lowering of the groundwater table due to over-pumping, ground subsidence from overdraft pumping, wildlife habitat loss, and urban sprawl.

The San Joaquin Valley includes some of the most extensively cultivated, irrigated, and chemically treated land in California; its water quality has been severely affected by land use and generally deteriorates downstream. Dissolved solid, nitrite plus nitrate, sulfate, and selenium concentrations have been rising in the San Joaquin Valley as a result of increasing irrigation return flow and reuse of stream water; runoff from dairies and feedlots has also affected nitrite and nitrate levels. The California State Water Resources Control Board has declared a 100 mile segment of the San Joaquin River as “Water Quality Limited.”

In the Sacramento River, median concentrations of most water pollutants are lower than in the San Joaquin River system. Weathering of metavolcanic and metasedimentary bedrock containing appreciable concentrations of fixed nitrogen in the Mokelumne River basin has contributed a significant amount of nitrate to surface waters.

### **3.2 Geographical Boundaries of Aggregate Ecoregion I**

Ecoregion I is composed of two separate segments that span along the west coast (Figure 2). The small, northern segment (Willamette Valley) begins near the southwestern border of Washington and continues south into Oregon. The second, larger segment (Central Valley) begins in north central California and continues south encompassing the middle portion of the State.

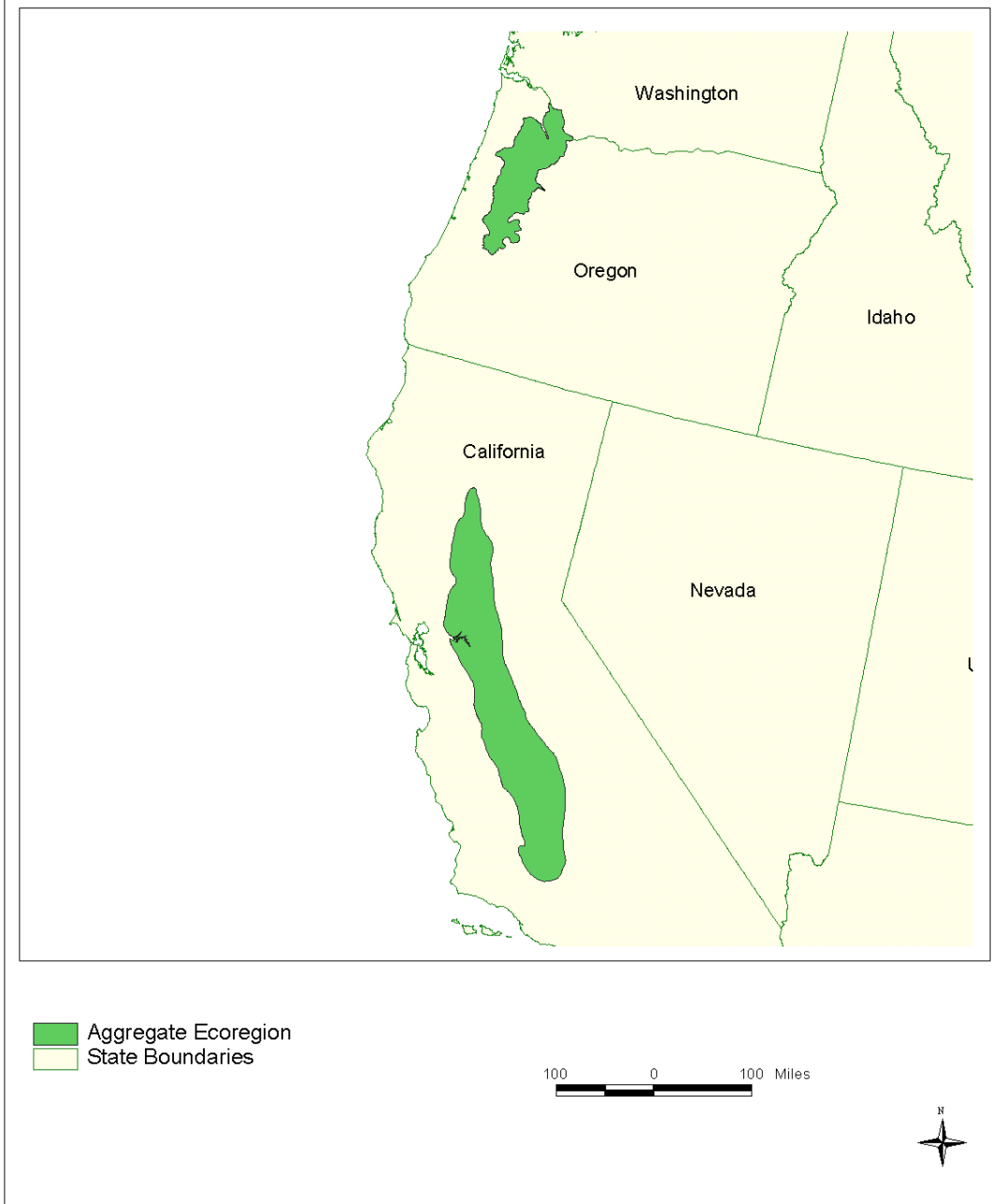
### **3.3 Level III Subcoregions Within Aggregate Ecoregion I**

There are two level III subcoregions contained within Aggregate Ecoregion I (Figure 3). The following are brief descriptions provided by Omernik (1999) of the climate, vegetative cover, topography, and other ecological information pertaining to these subcoregions.

#### **3. *Willamette Valley***

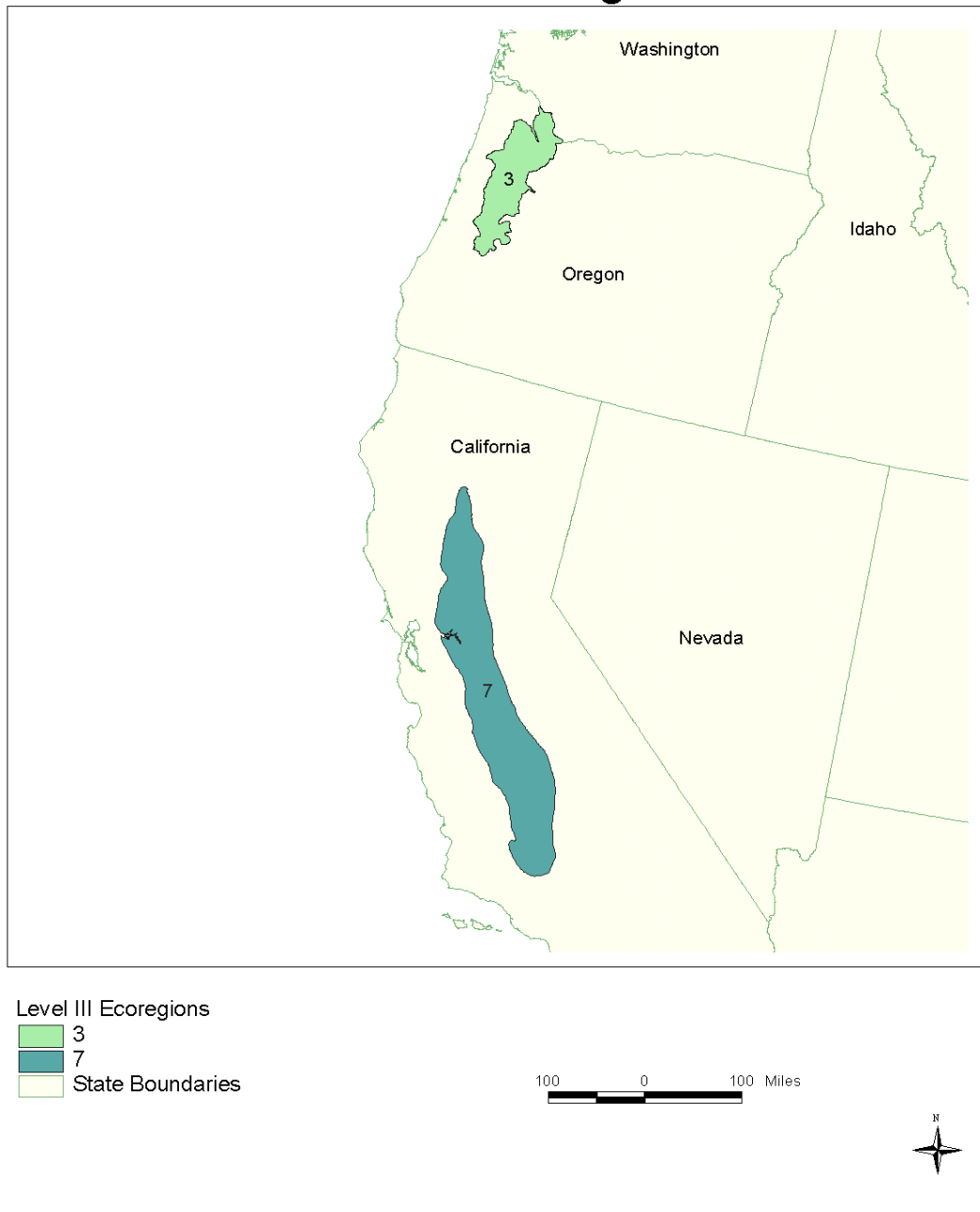
Rolling prairies, deciduous/coniferous forests, and extensive wetlands characterized the pre-19th century landscape of this broad, lowland valley. The Willamette Valley is distinguished from the adjacent Coast Range and Cascades by lower precipitation, less relief, and a different mosaic of vegetation. Landforms consist of terraces and floodplains, interlaced and surrounded by rolling hills. Productive soils and a temperate climate make it one of the most important agricultural areas in Oregon.

## Aggregate Nutrient Ecoregion 1



**Figure 2. Aggregate Ecoregion I.**

# Aggregate Nutrient Ecoregion 1 Level III Ecoregions



**Figure 3. Aggregate Ecoregion I with level III Ecoregions shown.**

## 7. Central California Valley

Flat, intensively farmed plains with long, hot dry summers and cool wet winters distinguish the Central California Valley from its neighboring Ecoregions that are either hilly or mountainous, forest or shrub covered, and generally nonagricultural. Nearly half of the region is in cropland, about three fourths of which is irrigated. Environmental concerns in the region include salinity due to evaporation of irrigation water, groundwater contamination from heavy use of agricultural chemicals, wildlife habitat loss, and urban sprawl.

### 3.4 Suggested Ecoregional Subdivisions or Adjustments

EPA recommends that the RTAG evaluate the adequacy of EPA nutrient ecoregional and subecoregional boundaries and refine them as needed to reflect local conditions. See the paper by Dale Robertson (USGS, 2001b) for an alternative approach to Ecoregions entitled “An Alternative Regarding the Scheme for Defining Nutrient Criteria for Rivers and Streams.”

## 4.0 DATA REVIEW FOR LAKES AND RESERVOIRS IN AGGREGATE ECOREGION I

This section describes the nutrient data EPA has collected and analyzed for this Ecoregion, including an assessment of data quantity and quality. The data tables present the data for each causal parameter (total phosphorus and total nitrogen, both reported and calculated from TKN and nitrite/nitrate) and the primary response variables (Secchi and chlorophyll *a*). EPA considers these parameters essential to nutrient assessment, because the first two are the main causative agents of enrichment and the two response variables are the early indicators of enrichment for most surface waters (see Chapter 5 of the *Lakes and Reservoirs Nutrient Criteria Technical Guidance Manual* [U.S. EPA, 2000a] for a complete discussion on choosing causal and response variables).

### 4.1 Data Sources

Data sets from Legacy STORET, NASQAN, NAWQA, and EPA Region 10 were used to assess nutrient conditions from 1990 to 2000. EPA recommends that the RTAGs identify additional data sources that can be used to supplement the data sets listed above. In addition, the RTAGs may utilize published literature values to support quantitative and qualitative analyses.

### 4.2 Historical Data from Aggregate Ecoregion I (TP, TN, chl *a*, and Secchi)

EPA recommends that States/Tribes assess long-term trends observed over the past 50 years to assess the relative stability of the systems. This information may be obtained from scientific literature or documentation of historical trends. To gain additional perspective on more recent trends, it is recommended that States and Tribes assess nutrient trends over the past 10 years (e.g., what do seasonal variations indicate?).

### 4.3 QA/QC of Data Sources

An initial quality screen of data was conducted using the rules presented in Appendix C. Data remaining after screening for duplications and other QA measures (e.g., poor or unreported analytical records, sampling errors or omissions, stations associated with outfalls, stormwater sewers, hazardous waste sites) were used in the statistical analyses.

States within Ecoregion I were contacted regarding the quality of their data and information on the methods used to sample and analyze their waters. The following States indicated standard methods or approved EPA methods were used: Washington and Oregon.

### 4.4 Data for All Lakes and Reservoirs Within Aggregate Ecoregion I

Figure 4 shows the location of the sampling stations within each subecoregion. Table 1 presents all data records for all parameters for Aggregate Ecoregion I and subecoregions within the Aggregate Ecoregion.

### 4.5 Statistical Analysis of Data

EPA's *Technical Guidance Manual for Developing Nutrient Criteria for Lakes and Reservoirs* describes two ways of establishing a reference condition. One method is to choose the upper 25th percentile (75th percentile) of a reference population of lakes. This is the preferred method. The 75th percentile is preferred by EPA because it is likely associated with minimally impacted conditions, will be protective of designated uses, and provides management flexibility. When reference lakes are not identified, the second method is to determine the lower 25th percentile of the population of all lakes within a region to attempt to approximate the preferred approach. The 25th percentile of the entire population was chosen by EPA to represent a surrogate for an actual reference population. Data analyses to date indicate that the lower 25th percentile from an entire population roughly approximates the 75th percentile for a reference population (see case studies for Minnesota lakes in the *Lakes and Reservoirs Nutrient Criteria Technical Guidance Document* [U.S. EPA, 2000a], the case study for Tennessee streams in the *Rivers and Streams Nutrient Criteria Technical Guidance Document* [U.S. EPA, 2000b], the letter from Tennessee Department of Environment and Conservation to Geoffrey Grubbs [TNDEC, 2000], the unpublished paper titled "Estimating the Natural Background Concentrations of Nutrients in Streams and Rivers of the Conterminous United States" [USGS, 2001a]), and the letter from Mathew Liebman, U.S. EPA Region 1 Nutrient Criteria Coordinator to Geoffrey Grubbs [U.S. EPA, 2000c]. New York State has also presented evidence that the 25th percentile and the 75th percentile compare well based on user perceptions of water resources (NYSDEC, 2000).



**Figure 4. Map of sampling locations within each level III Ecoregion.**

**Table 1. Lake and Reservoir records\* for Aggregate Ecoregion I—Willamette and Central Valleys**

	Aggregate Ecoregion I	Sub ecoR 3	Sub ecoR 7
# of lakes	8	8	
# of lake stations	12	12	
Key nutrient parameters (listed below)			
- # of records for Secchi depth	253	253	
- # of records for chlorophyll <i>a</i> (all methods)	63	63	
- # of records for total Kjeldhal nitrogen (TKN)	29	29	
- # of records for nitrite + nitrate (NO <sub>2</sub> +NO <sub>3</sub> )	36	36	
- # of records for total nitrogen (TN)	—	—	
- # of records for total phosphorus (TP)	141	141	
Total # of records for key nutrient parameters	522	522	

**Definitions:** (1) # of records refers to the total count of observations for that parameter over the entire decade (1990-1999) for that particular aggregate or subecoregion. These are counts for all seasons over that decade. (2) # of lake stations refers to the total number of lake and reservoir stations within the aggregate or subecoregion from which nutrient data were collected. Since lakes and reservoirs can cross ecoregional boundaries, it is important to note that only those portions of a lake or reservoir (and data associated with those stations) that exist within the Ecoregion are included within this table.

\*The number of lakes presented in this table is based on the number of lakes and reservoirs for which nutrient data were provided in the National Nutrient database. This does not imply that this is the total of lakes within the Ecoregion. States and Tribes should determine the representativeness of the tabular data by comparing this information with any additional material they may have.

Tables 2 and 3a-b present potential reference conditions for both the Aggregate Ecoregion and the subcoregions using both methods. However, the reference lake column is left blank because EPA does not have reference data and anticipates that States/Tribes will provide information on reference lakes. Tables 3a-b present potential reference conditions for lakes and reservoirs in the level III subcoregions within the Aggregate Ecoregion. Note that the footnotes for Table 2 apply to Tables 3a-b. Appendixes A and B provide a complete presentation of all descriptive statistics for both the Aggregate Ecoregion and the level III subcoregions.

Table 4 is presented for comparison purposes. It allows the reader to determine where, in the trophic state, the recommended reference conditions fall within traditionally viewed trophic boundaries.

#### **4.6 Classification of Lake/Reservoir Type**

Assessing the data by lake type should further reduce the variability in the data analysis. There were no readily available classification data in the national datasets used to develop these criteria. States and Tribes are strongly encouraged to classify their lakes before developing a final criterion.

#### **4.7 Summary of Data Reduction Methods**

All descriptive statistics were calculated using the medians for each lake within Ecoregion I for which data existed. For example, if one lake had 300 observations for phosphorus over the decade or 1 year's time, one median resulted. Each median from each lake was then used in calculating the percentiles for phosphorus for the aggregate nutrient Ecoregion/subcoregion (level III Ecoregion) by season and year (Figures 5a, 5b).

#### ***Preferred Data Choices and Recommendations When Data Are Missing***

- 1. Where data are missing** or are very low in total records for a given parameter, use 25th percentiles for parameters within an adjacent, similar subcoregion within the same aggregate nutrient Ecoregion, **or** when a similar subcoregion cannot be determined, use the 25th percentile for the Aggregate Ecoregion or consider the **lowest** 25th percentile from a subcoregion (level III) within the aggregate nutrient Ecoregion. Without data, one may assume that the subcoregion in question is as sensitive as the most sensitive subcoregion within the aggregate.
- 2. TN calculated:** When reported total nitrogen (TN) median values are lacking or very low in comparison to TKN and Nitrate/Nitrite-N values, the medians for TKN and nitrite/nitrate-N are added, resulting in a calculated TN value. The number of samples (N) for calculated TN is not filled in because it is represented by two subsamples of data: TKN and nitrite/nitrate-N. Therefore, N/A is placed in this box. (Note: TN calculated from TKN and  $\text{NO}_2 + \text{NO}_3$  should only be done on the same samples).



**Table 2. Reference conditions for Aggregate Ecoregion I lakes and reservoirs**

Parameter	No. of lakes N*	Reported values		25th percentiles based on all seasons data for the decade	Reference lakes§
		Min	Max	P25† all seasons‡	P75 all seasons
TKN (mg/L)	3	0.50	0.98	0.50 zz	
NO <sub>2</sub> +NO <sub>3</sub> -N (mg/L)	3	0.16	0.24	0.16 zz	
TN (mg/L) - calculated	NA	—	—	0.66 zz	
TN (mg/L) - reported	—	—	—	—	
TP (µg/L)	4	50	331.25	55	
Secchi (meters)	7	0.22	4	2.55	
Chlorophyll <i>a</i> (µg/L) - F	4	1.10	14	4.88	
Chlorophyll <i>a</i> (µg/L) - S	—	—	—	—	
Chlorophyll <i>a</i> (µg/L) - T	—	—	—	—	

\*N = largest value reported for a decadal season. TN calculated is based on the sum of TKN + NO<sub>2</sub>+NO<sub>3</sub>. TN reported is actual TN value reported in the database for one sample.

† 75th percentile for Secchi.

‡ Median for all seasons' 25th percentiles, e.g., this value was calculated from four seasons' 25th percentiles. If the seasonal 25th percentile (P25) TP values are: spring 10 µg/L, summer 15 µg/L, fall 12 µg/L, and winter 5 µg/L, the median value of all seasons P25 will be 11µg/L.

§ As determined by the Regional Technical Assistance Groups (RTAGs).

**Abbreviations:** P25, 25th percentile of all data; P75, 75th percentile of all data; F, Chlorophyll *a* measured by Fluorometric method with acid correction; S, Chlorophyll *a* measured by Spectrophotometric method with acid correction; T, Chlorophyll *a* *b* *c* measured by Trichromatic method; —, not applicable; NA, not available.

**Definitions:** (1) Number of Lakes refers to the largest number of lakes and reservoirs for which data existed for a given season within an aggregate nutrient Ecoregion. (2) Medians. All values (min, max, and 25<sup>th</sup> percentiles) included in the table are based on waterbody medians. All data for a particular parameter within a lake for the decade were reduced to one median for that lake. This prevents over-representation of individual waterbodies with a great deal of data versus those with fewer data points within the statistical analysis. (3) 25th percentile for all seasons is calculated by taking the median of the 4 seasonal 25<sup>th</sup> percentiles. If a season is missing, the median was calculated with 3 seasons of data. If fewer than 3 seasons were used to derive the median, the entry is flagged (z). (4) A 25th percentile for a season is best derived with data from a minimum of 4 lakes/season. However, this table provides 25th percentiles that were derived with fewer than 4 lakes/season in order to retain all information for all seasons. In calculating the 25th percentile for a season with fewer than 4 lake medians, the statistical program automatically used the minimum value within the fewer-than-4 population. If fewer than 4 lakes were used in developing a seasonal quartile and or all-seasons median, the entry is flagged (zz).

**Note:** For seasonal values, refer to Appendix A, "Descriptive Statistics Data Tables for Aggregate Ecoregion."

**Table 3a. Reference conditions for Ecoregion I lakes and reservoirs  
subcoregion 3**

Parameter	No. of lakes N*	Reported values		25th percentiles based on all seasons data for the decade	Reference lakes§
		Min	Max	P25† all seasons‡	P75 all seasons
TKN (mg/L)	3	0.50	0.98	0.50 zz	
NO <sub>2</sub> +NO <sub>3</sub> -N (mg/L)	3	0.16	0.24	0.16 zz	
TN (mg/L) - calculated		—	—	0.66 zz	
TN (mg/L) - reported	—	—	—	—	
TP (µg/L)	4	50	331.25	55	
Secchi (meters)	7	0.22	4	2.55	
Chlorophyll <i>a</i> (µg/L) - F	4	1.10	14	4.88	
Chlorophyll <i>a</i> (µg/L) - S	—	—	—	—	
Chlorophyll <i>a</i> (µg/L) - T	—	—	—	—	

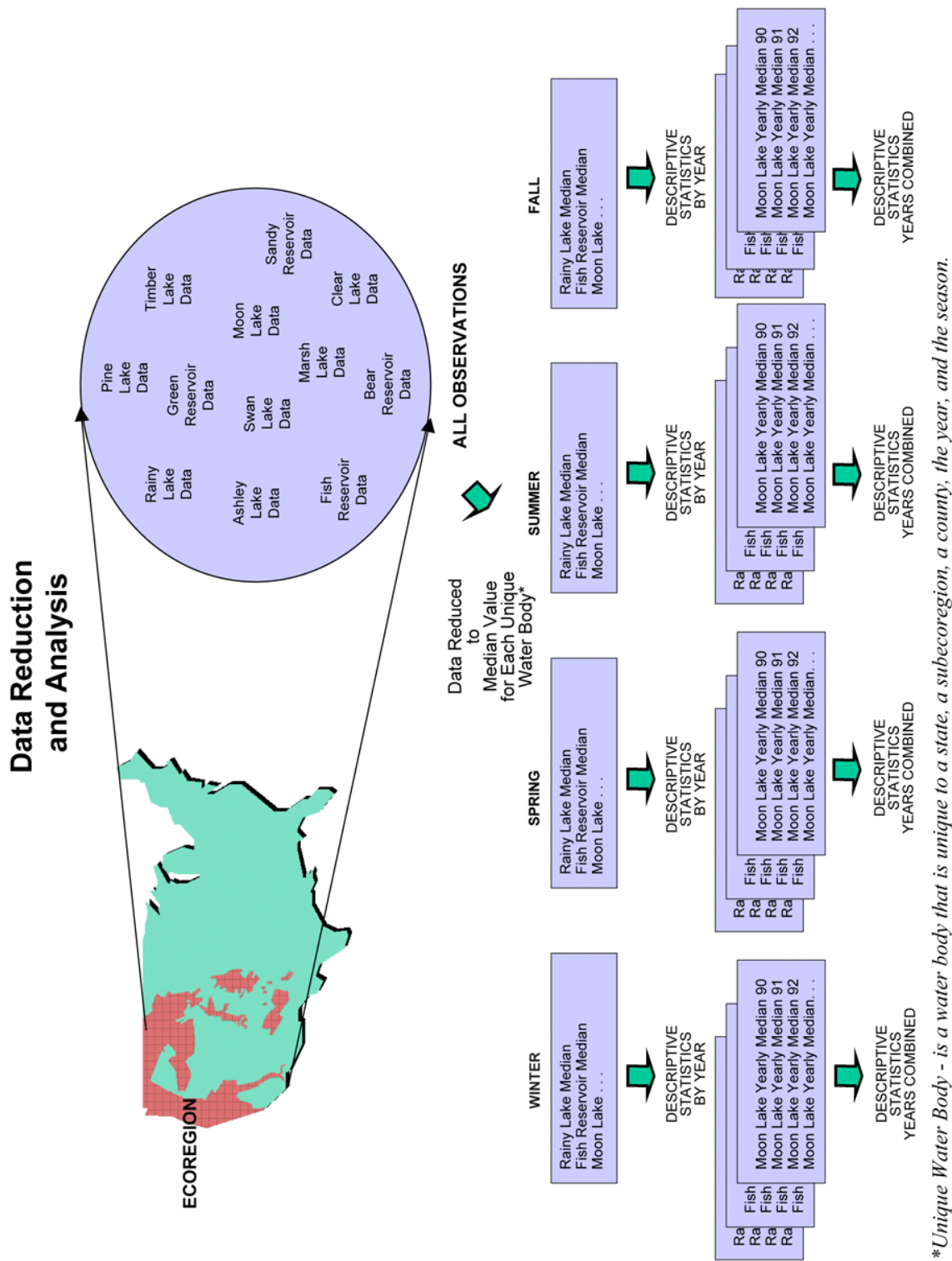
**Table 3b. Reference conditions for Ecoregion I lakes and reservoirs  
subcoregion 7**

No data were available to determine reference conditions for this subcoregion.

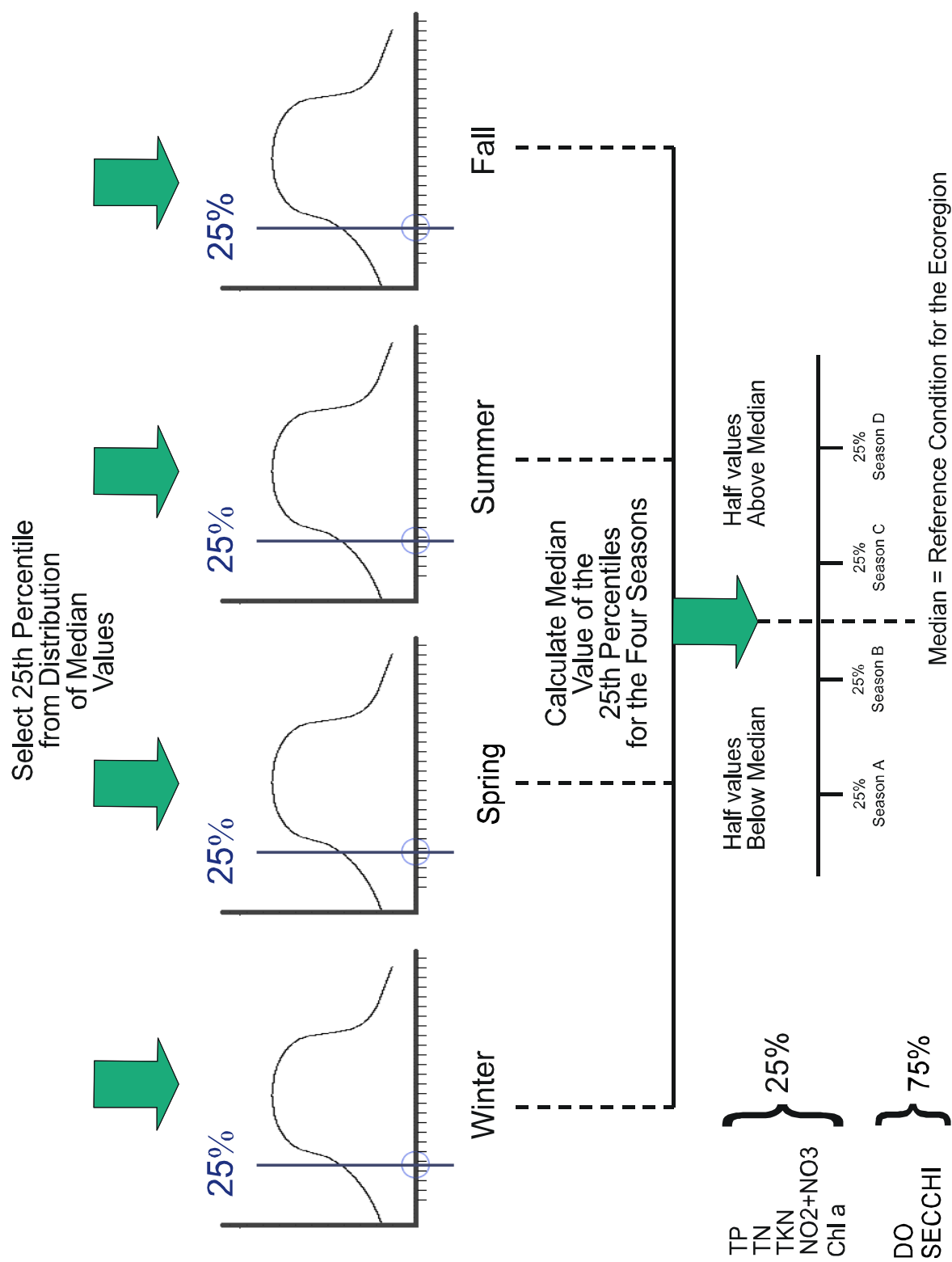
**Table 4. Changes in temperate lake attributes according to trophic state (adapted from Carlson and Simpson, 1995)**

TSI Value	SD (m)	TP (µg/L)	Attributes	Water Supply	Recreation	Fisheries
<30	>8	<6	Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion			Salmonid fisheries dominate
30-40	8-4	6-12	Hypolimnia of shallower lakes may become anoxic			Salmonid fisheries in deep lakes
40-50	4-2	12-24	Mesotrophy: Water moderately clear but increasing probability of hypolimnetic anoxia during summer	Iron and manganese evident during the summer. THM precursors exceed 0.1 mg/L and turbidity >1 NTU		Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	2-1	24-48	Eutrophy: Anoxic hypolimnia, macrophyte problems possible	Iron, manganese, taste, and odor problems worsen		Warm-water fisheries only. Bass may be dominant
60-70	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems		Weeds, algal scums, and low transparency discourage swimming and boating	
70-80	0.25-0.5	96-192	Hypereutrophy (light limited). Dense algae and macrophytes			
>80	<0.25	192-384	Algal scums, few macrophytes			Rough fish dominate, summer fish kills possible

**Note:** This table is provided to allow the reader to make comparisons between the ecoregional criteria provided in this document and traditional nutrient and biological endpoints.



**Figure 5a. Illustration of data reduction process for lake data.**



**Figure 5b. Illustration of reference condition calculation.**

3. **TN reported:** This is the median based on reported values for TN from the database.
4. **Chlorophyll *a*:** Medians based on all methods are reported; however, the acid-corrected medians are preferred to the uncorrected medians. In developing a reference condition from a particular method, it is recommended that the method with the most observations be used. Fluorometric and spectrophotometric observations are preferred over all other methods. However, when no data exist for fluorometric and spectrophotometric methods, trichromatic values may be used. Data from the various techniques are not interchangeable.
5. **Secchi depth:** The 75th percentile is reported for Secchi depth because this is the only variable for which the value of the parameter **increases** with greater clarity (for lakes and reservoirs only).
6. **Lack of data:** A dash (—) represents missing, inadequate, or inconclusive data. According to EPA statistical analyses, 5% or fewer of the reported observations are “below detection.” Because of this low incidence, these data were retained and factored into the statistical analysis as reported according to the protocols described in Appendix C, “Quality Control/Quality Assurance Rules.”

## 5.0 REFERENCE SITES AND CONDITIONS IN AGGREGATE ECOREGION I

Reference conditions represent the natural, least impacted conditions, or what is considered to be the most attainable conditions. This chapter compares the different reference conditions determined from the two methods and establishes which reference condition is most appropriate.

- *A priori* determination of reference sites. The preferred method for establishing reference condition is to choose the upper percentile of an *a priori* population of reference lakes. States and Tribes are encouraged to identify reference conditions based on this method.
- Statistical determination of reference conditions (25th percentile of entire database). See Tables 2 and 3a-b in Section 4.0.
- RTAG discussion and rationale for selection of reference sites and conditions in Ecoregion I.. The RTAG should compare the results derived from the two methods described above and present a rationale for the final selection of reference sites.

## 6.0 MODELS USED TO PREDICT OR VERIFY RESPONSE PARAMETERS

The RTAG is encouraged to identify and apply relevant models to support nutrient criteria development. There are three scenarios under which models may be used to derive criteria or support criteria development:

- Models for predicting correlations between causal and response variables
- Models used to verify reference conditions based on percentiles

- Regression models used to predict reference conditions in impacted areas

Appendix C of the Rivers and Streams Technical Guidance Manual (U.S. EPA, 2000b), and Chapter 9 of the Lakes and Reservoirs Technical Guidance Manual (U.S. EPA, 2000a) should be consulted for further details.

## **7.0 FRAMEWORK FOR REFINING RECOMMENDED NUTRIENT CRITERIA FOR LAKES AND RESERVOIRS IN AGGREGATE ECOREGION I**

Information on each of the following six weight-of-evidence factors is important to refine the criteria presented in this document. All elements should be addressed in developing criteria, as is expressed in EPA's nutrient criteria technical guidance manuals. It is our expectation that EPA Regions, States, and Tribes (as RTAGs) will consider these elements as States/Tribes develop their criteria. This section should be viewed as a worksheet (sections are left blank for this purpose) to assist in the refinement of nutrient criteria. If many of these elements are ultimately unaddressed, EPA may rely on the proposed reference conditions presented in Tables 3a-b and other literature and information readily available to the EPA Headquarters nutrient team to develop nutrient water quality recommendations for this Ecoregion.

### **7.1 Example Worksheet for Developing Aggregate Ecoregion and Subecoregion Nutrient Criteria**

*Literature sources:* \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

*Historical data and trends:* \_\_\_\_\_  
 \_\_\_\_\_  
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 \_\_\_\_\_

*Reference condition:* \_\_\_\_\_  
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 \_\_\_\_\_  
 \_\_\_\_\_

*Models:* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

*RTAG expert review and consensus:* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

*Downstream effects:* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## 7.2 Setting Seasonal Criteria

The recommendations presented in this document are based in part on medians of all the 25th percentile seasonal data (decadal), and as such reflect all seasons and not one particular season or year. It is recommended that States and Tribes monitor in all seasons to best assess compliance with the resulting criterion. States/Tribes may choose to develop criteria that reflect **each** particular season or **given season** or a **given year** when there is significant variability between seasons/years or designated uses that are specifically tied to one or more seasons of the year (e.g., recreation, fishing). Using the tables in Appendix A and B, one can set reference conditions based on a particular season or year and then develop a criterion based on each individual season. Obviously, this option is season-specific and would require increased monitoring within each season to assess compliance. If a case can be made that one season is more appropriate than another season or more appropriate than the annual median, criteria should be season specific. For example, in most parts of the country, spring and summer are the most common growth periods, so criteria for chlorophyll *a* and Secchi may be set for spring and summer only. However, caution should be used when developing criteria for TN and TP because the peak loading of these nutrients may take place in seasons other than summer, such as winter and spring. For these reasons, EPA developed annual criteria and provided additional seasonal information in appendices.

## 7.3 When Data/Reference Conditions Are Lacking

When data are unavailable to develop a reference condition for a particular parameter(s) within a subcoregion, EPA recommends one of three options: (1) use data from a similar neighboring subcoregion (e.g., if data are few or nonexistent for the Northern Cascades,



consider using the data and reference conditions developed for the Cascades); (2) use the 25th percentiles for the Aggregate Ecoregion; or (3) consider using the lowest of the yearly medians for that parameter calculated for all the subcoregions within the Aggregate Ecoregion.

## **7.4 Site-Specific Criteria Development**

Criteria may be refined in a number of ways. The best way is to follow the critical elements of criteria development as well as to refer to the *Lakes and Reservoirs Nutrient Criteria Technical Guidance Manual* (U.S. EPA, 2000a). The Technical Guidance Manual presents sections on each of the following factors to consider in setting criteria:

- Refinements to Ecoregions (Chapter 3). See paper by Dale Robertson (USGS, 2001b), an alternative approach to ecoregions entitled “An Alternative Regarding the Scheme for Defining Nutrient Criteria for Rivers and Streams.”
- Classification of waterbodies (Chapter 3)
- Setting seasonal criteria to reflect major seasonal climate differences and accounting for significant or cyclical precipitation events (high-flow/low-flow conditions) (Chapter 7)
- Setting criteria for reservoirs only. (The technical guidance manual recommends that data be separated for lakes and reservoirs and treated independently if possible because of differing physical conditions that occur in lakes and reservoirs. In this document all data from both reservoirs and lakes were considered together since STORET does not allow for the differentiation of data except by waterbody name.)

## **8.0 LITERATURE CITED**

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## **9.0 APPENDICES**

- A. Descriptive Statistics Data Tables for Aggregate Ecoregion
- B. Descriptive Statistics Data Tables for Level III Subcoregions Within Aggregate Ecoregion
- C. Quality Control/Quality Assurance Rules

## **APPENDIX A**

### **Descriptive Statistics Data Tables for Aggregate Ecoregion**



Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Decade and Season  
from 1990 to 1996  
Chloro\_A\_Fluor\_cor\_ug\_L

season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
FALL	3	5.54	1.1000	10.00	4.45	2.57	80	1.10	1.10	5.53	10.00	10.00
SPRING	3	9.23	4.8830	14.00	4.57	2.64	50	4.88	4.88	8.80	14.00	14.00
SUMMER	4	17.67	1.0500	37.00	14.82	7.41	84	1.05	7.83	16.31	27.50	37.00

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Decade and Season  
from 1990 to 1998  
Dissolved\_Oxygen\_mg\_L

season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
FALL	4	9.34	7.4500	11.60	1.71	0.85	18	7.45	8.30	9.16	10.39	11.60
SPRING	3	10.61	9.3750	11.40	1.08	0.62	10	9.38	9.38	11.05	11.40	11.40
SUMMER	4	8.84	6.7000	9.75	1.43	0.72	16	6.70	8.05	9.45	9.63	9.75
WINTER	2	12.20	11.598	12.80	0.85	0.60	7	11.60	11.60	12.20	12.80	12.80

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Decade and Season  
from 1990 to 1996  
Nitrite\_Nitrate\_NO2\_NO3\_mg\_L

season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
FALL	3	0.08	.06000	0.10	0.02	0.01	26	0.06	0.06	0.09	0.10	0.10
SPRING	2	0.31	.25000	0.38	0.09	0.06	28	0.25	0.25	0.31	0.38	0.38
SUMMER	3	0.01	.00000	0.02	0.01	0.01	125	0.00	0.00	0.01	0.02	0.02
WINTER	2	0.49	.28000	0.70	0.30	0.21	61	0.28	0.28	0.49	0.70	0.70

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I Lakes and Reservoirs Descriptive Statistics by Decade and Season from 1990 to 1993 Nitrogen_Tot_Kjeldhal_mg_L										
season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	P75
FALL	2	0.68	.60000	0.75	0.11	0.07	16	0.60	0.60	0.75
SPRING	2	0.45	.35000	0.55	0.14	0.10	31	0.35	0.35	0.55
SUMMER	2	1.30	1.3000	1.30	0.00	0.00	0	1.30	1.30	1.30
WINTER	3	0.83	.40000	1.20	0.40	0.23	48	0.40	0.40	1.20
Data were not always available for all years.										

4

Aggregate Nutrient Ecoregion: I Lakes and Reservoirs Descriptive Statistics by Decade and Season from 1990 to 1998 SECCHI_m										
season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	P75
FALL	6	1.08	.23000	3.00	1.11	0.45	103	0.23	0.28	1.80
SPRING	6	1.87	.33750	5.60	2.15	0.88	115	0.34	0.40	3.30
SUMMER	7	1.92	.21000	5.00	1.97	0.75	103	0.21	0.24	3.90
WINTER	4	0.26	.00000	0.46	0.20	0.10	79	0.00	0.10	0.41
Data were not always available for all years.										

5

Aggregate Nutrient Ecoregion: I Lakes and Reservoirs Descriptive Statistics by Decade and Season from 1990 to 1998 Total_Phosphorus_ug_L										
season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	P75
FALL	4	196.25	25.000	382.50	180.08	90.04	92	25.00	42.50	188.75
SPRING	3	105.00	50.000	150.00	50.74	29.30	48	50.00	50.00	150.00
SUMMER	4	215.00	50.000	385.00	179.58	89.79	84	50.00	60.00	370.00
WINTER	4	173.13	80.000	280.00	83.10	41.55	48	80.00	115.00	231.25
Data were not always available for all years.										

6

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Decade and Season  
from 1996 to 1998  
pH\_S\_U

season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
FALL	2	7.09	6.5000	7.67	0.83	0.59	12	6.50	6.50	7.09	7.67	7.67
SPRING	1	7.40	7.4000	7.40	.	.	.	7.40	7.40	7.40	7.40	7.40
SUMMER	2	7.45	7.3000	7.60	0.21	0.15	3	7.30	7.30	7.45	7.60	7.60
WINTER	1	7.60	7.6000	7.60	.	.	.	7.60	7.60	7.60	7.60	7.60

Data were not always available for all years.





## **APPENDIX B**

### **Descriptive Statistics Data Tables for Level III Subcoregions Within Aggregate Ecoregion**



Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1996  
Chloro\_A\_Fluor\_cor\_ug\_L

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	3	5.54	1.1000	10.00	4.45	2.57	80	1.10	1.10	5.53	10.0	10.0
3	SPRING	3	9.23	4.8830	14.00	4.57	2.64	50	4.88	4.88	8.80	14.0	14.0
3	SUMMER	4	17.67	1.0500	37.00	14.8	7.41	84	1.05	7.83	16.3	27.5	37.0

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1998  
Dissolved\_Oxygen\_mg\_L

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	4	9.34	7.4500	11.60	1.71	0.85	18	7.45	8.30	9.16	10.4	11.6
3	SPRING	3	10.61	9.3750	11.40	1.08	0.62	10	9.38	9.38	11.1	11.4	11.4
3	SUMMER	4	8.84	6.7000	9.75	1.43	0.72	16	6.70	8.05	9.45	9.63	9.75
3	WINTER	2	12.20	11.598	12.80	0.85	0.60	7	11.6	11.6	12.2	12.8	12.8

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1996  
Nitrite\_Nitrate\_NO2\_NO3\_mg\_L

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	3	0.08	.06000	0.10	0.02	0.01	26	0.06	0.06	0.09	0.10	0.10
3	SPRING	2	0.31	.25000	0.38	0.09	0.06	28	0.25	0.25	0.31	0.38	0.38
3	SUMMER	3	0.01	.00000	0.02	0.01	0.01	125	0.00	0.00	0.01	0.02	0.02
3	WINTER	2	0.49	.28000	0.70	0.30	0.21	61	0.28	0.28	0.49	0.70	0.70

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1993  
Nitrogen\_Tot\_Kjeldhal\_mg\_L

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	2	0.68	.60000	0.75	0.11	0.07	16	0.60	0.60	0.68	0.75	0.75
3	SPRING	2	0.45	.35000	0.55	0.14	0.10	31	0.35	0.35	0.45	0.55	0.55
3	SUMMER	2	1.30	1.3000	1.30	0.00	0.00	0	1.30	1.30	1.30	1.30	1.30
3	WINTER	3	0.83	.40000	1.20	0.40	0.23	48	0.40	0.40	0.90	1.20	1.20

Data were not always available for all years.

5

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1998  
SECCHI\_m

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	6	1.08	.23000	3.00	1.11	0.45	103	0.23	0.28	0.58	1.80	3.00
3	SPRING	6	1.87	.33750	5.60	2.15	0.88	115	0.34	0.40	0.79	3.30	5.60
3	SUMMER	7	1.92	.21000	5.00	1.97	0.75	103	0.21	0.24	1.00	3.90	5.00
3	WINTER	4	0.26	.00000	0.46	0.20	0.10	79	0.00	0.10	0.28	0.41	0.46

Data were not always available for all years.

6

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1990 to 1998  
Total\_Phosphorus\_ug\_L

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	4	196.25	25.000	382.50	180	90.0	92	25.0	42.5	189	350	383
3	SPRING	3	105.00	50.000	150.00	50.7	29.3	48	50.0	50.0	115	150	150
3	SUMMER	4	215.00	50.000	385.00	180	89.8	84	50.0	60.0	213	370	385
3	WINTER	4	173.13	80.000	280.00	83.1	41.6	48	80.0	115	166	231	280

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I 7

Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Decade and Season  
from 1996 to 1998  
pH\_S\_U

subecoregion	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	FALL	2	7.09	6.5000	7.67	0.83	0.59	12	6.50	6.50	7.09	7.67	7.67
3	SPRING	1	7.40	7.4000	7.40	.	.	.	7.40	7.40	7.40	7.40	7.40
3	SUMMER	2	7.45	7.3000	7.60	0.21	0.15	3	7.30	7.30	7.45	7.60	7.60
3	WINTER	1	7.60	7.6000	7.60	.	.	.	7.60	7.60	7.60	7.60	7.60

Data were not always available for all years.

Aggregate Nutrient Ecoregion: I 1

Lakes and Reservoirs  
Descriptive Statistics by Subecoregion, Year and Season  
from 1990 to 1996  
Chloro\_A\_Fluor\_cor\_ug\_L

subecoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	SUMMER	2	27.50	18.000	37.00	13.44	9.50	49	18.00	18.00	27.50	37.00	37.00
3	1991	FALL	1	2.20	2.2000	2.20	.	.	.	2.20	2.20	2.20	2.20	2.20
3	1991	SUMMER	2	41.00	39.000	43.00	2.83	2.00	7	39.00	39.00	41.00	43.00	43.00
3	1992	FALL	2	9.43	8.8500	10.00	0.81	0.58	9	8.85	8.85	9.43	10.00	10.00
3	1992	SPRING	2	11.40	8.8000	14.00	3.68	2.60	32	8.80	8.80	11.40	14.00	14.00
3	1992	SUMMER	2	5.98	5.5500	6.40	0.60	0.43	10	5.55	5.55	5.98	6.40	6.40
3	1996	FALL	1	1.10	1.1000	1.10	.	.	.	1.10	1.10	1.10	1.10	1.10
3	1996	SPRING	1	4.88	4.8830	4.88	.	.	.	4.88	4.88	4.88	4.88	4.88
3	1996	SUMMER	2	7.83	1.0500	14.61	9.59	6.78	122	1.05	1.05	7.83	14.61	14.61

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1990 to 1998  
Dissolved\_Oxygen\_mg\_L

2

subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	SUMMER	2	9.45	9.4000	9.50	0.07	0.05	1	9.40	9.40	9.45	9.50	9.50
3	1991	FALL	2	8.65	8.3000	9.00	0.49	0.35	6	8.30	8.30	8.65	9.00	9.00
3	1991	SUMMER	2	9.50	9.4000	9.60	0.14	0.10	1	9.40	9.40	9.50	9.60	9.60
3	1992	FALL	2	9.68	9.3500	10.00	0.46	0.32	5	9.35	9.35	9.68	10.00	10.00
3	1992	SPRING	2	9.80	9.3000	10.30	0.71	0.50	7	9.30	9.30	9.80	10.30	10.30
3	1992	SUMMER	2	8.40	8.0000	8.80	0.57	0.40	7	8.00	8.00	8.40	8.80	8.80
3	1993	SPRING	2	12.65	12.500	12.80	0.21	0.15	2	12.50	12.50	12.65	12.80	12.80
3	1993	WINTER	1	12.80	12.800	12.80	.	.	.	12.80	12.80	12.80	12.80	12.80
3	1996	FALL	2	9.73	7.8600	11.60	2.64	1.87	27	7.86	7.86	9.73	11.60	11.60
3	1996	SPRING	1	9.38	9.3750	9.38	.	.	.	9.38	9.38	9.38	9.38	9.38
3	1996	SUMMER	2	9.24	8.7350	9.75	0.72	0.51	8	8.74	8.74	9.24	9.75	9.75
3	1996	WINTER	1	12.44	12.440	12.44	.	.	.	12.44	12.44	12.44	12.44	12.44
3	1997	FALL	1	7.18	7.1800	7.18	.	.	.	7.18	7.18	7.18	7.18	7.18
3	1997	SPRING	1	9.87	9.8700	9.87	.	.	.	9.87	9.87	9.87	9.87	9.87
3	1997	SUMMER	1	6.60	6.5950	6.60	.	.	.	6.60	6.60	6.60	6.60	6.60
3	1997	WINTER	1	10.76	10.755	10.76	.	.	.	10.76	10.76	10.76	10.76	10.76
3	1998	FALL	1	7.45	7.4500	7.45	.	.	.	7.45	7.45	7.45	7.45	7.45
3	1998	SPRING	1	6.65	6.6500	6.65	.	.	.	6.65	6.65	6.65	6.65	6.65
3	1998	SUMMER	1	6.70	6.7000	6.70	.	.	.	6.70	6.70	6.70	6.70	6.70

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1990 to 1996  
Nitrite\_Nitrate\_NO2\_NO3\_mg\_L

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subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	SUMMER	2	0.02	.00500	0.03	0.02	0.01	101	0.01	0.01	0.02	0.03	0.03
3	1991	FALL	2	0.05	.04000	0.05	0.01	0.01	16	0.04	0.04	0.05	0.05	0.05
3	1991	SUMMER	2	0.01	.00500	0.02	0.01	0.01	85	0.01	0.01	0.01	0.02	0.02
3	1992	FALL	2	0.14	.12000	0.17	0.03	0.02	22	0.12	0.12	0.14	0.17	0.17
3	1992	SPRING	2	0.23	.23000	0.23	0.00	0.00	0	0.23	0.23	0.23	0.23	0.23
3	1992	SUMMER	2	0.03	.00500	0.05	0.03	0.02	114	0.01	0.01	0.03	0.05	0.05
3	1993	SPRING	2	0.40	.27000	0.52	0.18	0.13	45	0.27	0.27	0.40	0.52	0.52
3	1993	WINTER	2	0.49	.28000	0.70	0.30	0.21	61	0.28	0.28	0.49	0.70	0.70
3	1996	FALL	1	0.06	.06000	0.06	.	.	.	0.06	0.06	0.06	0.06	0.06
3	1996	SUMMER	1	0.00	.00000	0.00	.	.	.	0.00	0.00	0.00	0.00	0.00

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1990 to 1993  
Nitrogen\_Tot\_Kjeldhal\_mg\_L

4

subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	SUMMER	2	1.60	1.5000	1.70	0.14	0.10	9	1.50	1.50	1.60	1.70	1.70
3	1990	WINTER	1	1.20	1.2000	1.20	.	.	.	1.20	1.20	1.20	1.20	1.20
3	1991	FALL	2	0.75	.70000	0.80	0.07	0.05	9	0.70	0.70	0.75	0.80	0.80
3	1991	SUMMER	2	1.30	1.3000	1.30	0.00	0.00	0	1.30	1.30	1.30	1.30	1.30
3	1992	FALL	2	0.60	.50000	0.70	0.14	0.10	24	0.50	0.50	0.60	0.70	0.70
3	1992	SPRING	2	0.45	.40000	0.50	0.07	0.05	16	0.40	0.40	0.45	0.50	0.50
3	1992	SUMMER	2	0.83	.65000	1.00	0.25	0.18	30	0.65	0.65	0.83	1.00	1.00
3	1993	SPRING	2	0.45	.30000	0.60	0.21	0.15	47	0.30	0.30	0.45	0.60	0.60
3	1993	WINTER	2	0.65	.40000	0.90	0.35	0.25	54	0.40	0.40	0.65	0.90	0.90

Aggregate Nutrient Ecoregion: I  
Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1990 to 1998  
SECCHI\_m

5

subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	FALL	1	3.00	3.0000	3.00	.	.	.	3.00	3.00	3.00	3.00	3.00
3	1990	SPRING	1	5.60	5.6000	5.60	.	.	.	5.60	5.60	5.60	5.60	5.60
3	1990	SUMMER	1	3.90	3.9000	3.90	.	.	.	3.90	3.90	3.90	3.90	3.90
3	1991	FALL	1	0.40	.40000	0.40	.	.	.	0.40	0.40	0.40	0.40	0.40
3	1991	SUMMER	1	0.30	.30000	0.30	.	.	.	0.30	0.30	0.30	0.30	0.30
3	1991	WINTER	1	0.20	.20000	0.20	.	.	.	0.20	0.20	0.20	0.20	0.20
3	1992	FALL	4	0.52	.23000	1.20	0.46	0.23	89	0.23	0.26	0.32	0.78	1.20
3	1992	SPRING	3	1.30	.30000	3.30	1.73	1.00	133	0.30	0.30	0.30	3.30	3.30
3	1992	SUMMER	4	0.86	.21000	2.70	1.23	0.61	142	0.21	0.23	0.27	1.50	2.70
3	1992	WINTER	1	0.20	.20000	0.20	.	.	.	0.20	0.20	0.20	0.20	0.20
3	1993	FALL	2	1.40	.40000	2.40	1.41	1.00	101	0.40	0.40	1.40	2.40	2.40
3	1993	SPRING	3	0.45	.37500	0.50	0.07	0.04	15	0.38	0.38	0.47	0.50	0.50
3	1993	SUMMER	2	1.63	.40000	2.85	1.73	1.23	107	0.40	0.40	1.63	2.85	2.85
3	1993	WINTER	2	0.41	.36000	0.46	0.07	0.05	17	0.36	0.36	0.41	0.46	0.46
3	1996	FALL	1	0.75	.75000	0.75	.	.	.	0.75	0.75	0.75	0.75	0.75
3	1996	SPRING	1	1.10	1.1000	1.10	.	.	.	1.10	1.10	1.10	1.10	1.10
3	1996	SUMMER	2	2.75	.50000	5.00	3.18	2.25	116	0.50	0.50	2.75	5.00	5.00
3	1997	FALL	1	0.50	.50000	0.50	.	.	.	0.50	0.50	0.50	0.50	0.50
3	1997	SPRING	1	1.00	1.0000	1.00	.	.	.	1.00	1.00	1.00	1.00	1.00
3	1997	SUMMER	1	1.00	1.0000	1.00	.	.	.	1.00	1.00	1.00	1.00	1.00
3	1997	WINTER	1	0.00	.00000	0.00	.	.	.	0.00	0.00	0.00	0.00	0.00
3	1998	FALL	1	0.85	.85000	0.85	.	.	.	0.85	0.85	0.85	0.85	0.85
3	1998	SPRING	1	1.30	1.3000	1.30	.	.	.	1.30	1.30	1.30	1.30	1.30
3	1998	SUMMER	1	1.10	1.1000	1.10	.	.	.	1.10	1.10	1.10	1.10	1.10

Aggregate Nutrient Ecoregion: I

6

Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1990 to 1998  
Total\_Phosphorus\_ug\_L

subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1990	SUMMER	2	400.00	390.00	410.00	14.14	10.00	4	390.00	390.00	400.00	410.00	410.00
3	1990	WINTER	1	280.00	280.00	280.00	.	.	.	280.00	280.00	280.00	280.00	280.00
3	1991	FALL	2	485.00	430.00	540.00	77.78	55.00	16	430.00	430.00	485.00	540.00	540.00
3	1991	SUMMER	1	385.00	385.00	385.00	.	.	.	385.00	385.00	385.00	385.00	385.00
3	1992	FALL	2	215.00	205.00	225.00	14.14	10.00	7	205.00	205.00	215.00	225.00	225.00
3	1992	SPRING	2	150.00	120.00	180.00	42.43	30.00	28	120.00	120.00	150.00	180.00	180.00
3	1992	SUMMER	2	257.50	215.00	300.00	60.10	42.50	23	215.00	215.00	257.50	300.00	300.00
3	1993	SPRING	2	115.00	110.00	120.00	7.07	5.00	6	110.00	110.00	115.00	120.00	120.00
3	1993	WINTER	2	115.00	80.000	150.00	49.50	35.00	43	80.00	80.00	115.00	150.00	150.00
3	1996	FALL	2	42.50	25.000	60.00	24.75	17.50	58	25.00	25.00	42.50	60.00	60.00
3	1996	SPRING	1	30.00	30.000	30.00	.	.	.	30.00	30.00	30.00	30.00	30.00
3	1996	SUMMER	2	60.00	50.000	70.00	14.14	10.00	24	50.00	50.00	60.00	70.00	70.00
3	1996	WINTER	1	215.00	215.00	215.00	.	.	.	215.00	215.00	215.00	215.00	215.00
3	1997	FALL	1	60.00	60.000	60.00	.	.	.	60.00	60.00	60.00	60.00	60.00
3	1997	SPRING	1	50.00	50.000	50.00	.	.	.	50.00	50.00	50.00	50.00	50.00
3	1997	SUMMER	1	40.00	40.000	40.00	.	.	.	40.00	40.00	40.00	40.00	40.00
3	1997	WINTER	1	150.00	150.00	150.00	.	.	.	150.00	150.00	150.00	150.00	150.00
3	1998	FALL	1	30.00	30.000	30.00	.	.	.	30.00	30.00	30.00	30.00	30.00
3	1998	SPRING	1	100.00	100.00	100.00	.	.	.	100.00	100.00	100.00	100.00	100.00
3	1998	SUMMER	1	100.00	100.00	100.00	.	.	.	100.00	100.00	100.00	100.00	100.00

Aggregate Nutrient Ecoregion: I

7

Lakes and Reservoirs  
Descriptive Statistics by Subcoregion, Year and Season  
from 1996 to 1998  
pH\_S\_U

subcoregion	year	season	N	MEAN	MIN	MAX	STDDEV	STDERR	CV	P5	P25	MEDIAN	P75	P95
3	1996	FALL	2	7.15	6.5000	7.80	0.92	0.65	13	6.50	6.50	7.15	7.80	7.80
3	1996	SPRING	1	6.92	6.9150	6.92	.	.	.	6.92	6.92	6.92	6.92	6.92
3	1996	SUMMER	2	7.57	7.3000	7.84	0.38	0.27	5	7.30	7.30	7.57	7.84	7.84
3	1996	WINTER	1	7.65	7.6500	7.65	.	.	.	7.65	7.65	7.65	7.65	7.65
3	1997	FALL	1	7.60	7.6000	7.60	.	.	.	7.60	7.60	7.60	7.60	7.60
3	1997	SPRING	1	7.80	7.8000	7.80	.	.	.	7.80	7.80	7.80	7.80	7.80
3	1997	SUMMER	1	7.50	7.5000	7.50	.	.	.	7.50	7.50	7.50	7.50	7.50
3	1997	WINTER	1	7.55	7.5500	7.55	.	.	.	7.55	7.55	7.55	7.55	7.55
3	1998	FALL	1	7.67	7.6700	7.67	.	.	.	7.67	7.67	7.67	7.67	7.67
3	1998	SPRING	1	7.40	7.4000	7.40	.	.	.	7.40	7.40	7.40	7.40	7.40
3	1998	SUMMER	1	7.60	7.6000	7.60	.	.	.	7.60	7.60	7.60	7.60	7.60



## **APPENDIX C**

### **Quality Control/Quality Assurance Rules**



# Continued Support for the Compilation and Analysis of National Nutrient Data

## 3 Nutrient Ecoregion/Waterbody Type Summary Chapters

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## 1.0 BACKGROUND

The Nutrient Criteria Program initiated the development of a national Nutrient Criteria Database application that is used to store and analyze nutrient data. The ultimate use of these data is to derive ecoregion specific nutrient criteria. EPA converted STORage and RETrieval (STORET) legacy data, National Stream Quality Accounting Network (NASQAN) data, National Water-Quality Assessment (NAWQA) data, and other relevant nutrient data from universities and States/Tribes into the database. The data imported into the Nutrient Criteria Database are used to develop national nutrient criteria recommendations.

### 1.1 Purpose

The purpose of this deliverable is to provide EPA with information regarding the database used to create the statistical reports which will be used to derive ecoregion-specific nutrient criteria for Level III ecoregions. There are fourteen aggregate nutrient ecoregions. Each aggregate nutrient ecoregion is divided into smaller ecoregions (subcoregions) referred to as Level III ecoregions. EPA will determine criteria for the waterbody types and Level III ecoregions within the following aggregate nutrient ecoregions:

- Lakes and Reservoirs
  - Aggregate Nutrient ecoregions: 3, 4, 5, and 14
- Rivers and Streams
  - Aggregate Nutrient ecoregions: 1, 4, 5, 8, and 10

### 1.2 References

This section lists documents that contain baselines, standards, guidelines, policies, and references that apply to the data analysis. Listed editions were valid at the time of publication. All documents are subject to revision, but these specific editions govern the concepts described in this document.

*Nutrient Criteria Technical Guidance Document: Lakes and Reservoirs (Draft).* EPA, Office of Water, EPA 822-D-99-001, April 1999.

*Nutrient Criteria Technical Guidance Manual: Rivers and Streams (Draft).* EPA, Office of Water, EPA 822-D-99-003, September 1999.

*Guidance for Data Quality Assessment: Practical Methods for Data Analysis.* EPA, Office of Research and Development, EPA QA/G-9, January 1998.

## 2.0 QA/QC PROCEDURES

In order to develop nutrient criteria, EPA needed to obtain nutrient data from the states. EPA requested nutrient data from the states and forwarded the data sets to INDUS via e-mail and/or

US mail. In addition, EPA tasked INDUS to convert data from three national data sets. EPA provided INDUS with a Legacy STORET extraction to convert into the database. The United States Geologic Survey (USGS) sent INDUS a CD-ROM with NASQAN data to convert. INDUS downloaded NAWQA files from the USGS Web site to convert the data. In total, INDUS converted and imported the following national and state data sets into the Nutrient Criteria Database:

- Legacy STORET
- NAWQA
- NASQAN
- EPA Region 1
- EPA Region 2 - Lake Champlain Monitoring Project
- EPA Region 2 - NYSDEC Finger Lakes Monitoring Program
- EPA Region 2 - NY Citizens Lake Assessment Program
- EPA Region 2 - Lake Classification and Inventory Survey
- EPA Region 2 - NYCDEP (1990-1998)
- EPA Region 2 - NYCDEP (Storm Event data)
- EPA Region 2 - New Jersey Nutrient Data ( Tidal Waters)
- EPA Region 5
- EPA Region 3
- EPA Region 3 - Nitrite Data
- EPA Region 3 - Choptank River files
- EPA Region 4 - Tennessee Valley Authority
- EPA Region 7 - Central Plains Center for BioAssessment (CPCB)
- EPA Region 7 - REMAP
- EPA Region 2 - Delaware River Basin Commission (1990-1998)
- EPA Region 3 - PA Lake Data
- EPA Region 3 - University of Delaware
- EPA Region 10
- University of Auburn
- EPA Region 8 - MT and WY
- EPA Region 9
- Suffolk County
- NYCDEC
- NY Lakes Morphometry
- EPA Region 8 - South Dakota
- EPA Region 8 - Colorado Reservoir
- EPA Region 4
- EPA Region 10 - Lake Data
- EPA Region 7 - Central Plains Center for BioAssessment (CPCB) 2
- EPA Region 8 - North Dakota
- EPA Region 8 - Eagle River
- EPA Region 8 - Utah
- Florida

As part of the conversion process, INDUS performed a number of Quality Assurance/Quality Control (QA/QC) steps to ensure that the data were properly converted into the Nutrient Criteria Database. Sections 2.1 and 2.2 explain the steps performed by INDUS to convert the data.

## **2.1 National Data Sets**

INDUS converted three national data sets into the Nutrient Criteria Database: Legacy STORET data, NASQAN data, and NAWQA data. A previous EPA contractor performed the extraction of Legacy STORET data and documented the QA/QC procedures used on the data. This documentation is included in Appendix A. INDUS performed minimal QA/QC on the Legacy STORET data set because the previous contractor completed the steps outlined in Appendix A. INDUS and EPA also agreed to convert the NAWQA and NASQAN data sets with minimal QA/QC on the assumption that the source agency, the USGS, QA/QC'd the data.

For each of the three national data sets, INDUS ran queries to determine if 1) samples existed without results and 2) if stations existed without samples. Per Task Order Project Officer (TOPO) direction, these records were deleted from the system. For analysis purposes, EPA determined that there was no need to keep station records with no samples and sample records with no results. INDUS also confirmed that each data set contained no duplicate records.

In addition, INDUS deleted all composite results from the Legacy STORET data. Per TOPO direction, it was decided that composite sample results would not be used in the statistical analysis.

## **2.2 State Data**

Each state data set was delivered in a unique format. Many of the data sets were delivered to INDUS without corresponding documentation. INDUS analyzed each state data set in order to determine which parameters should be converted for analysis. INDUS obtained a master parameter table from EPA and converted the parameters in the state data sets according to those that were present in the EPA parameter table. INDUS converted all of the data elements in the state data sets that mapped directly to the Nutrient Criteria Database; data elements that did not map to the Nutrient Criteria Database were not converted. In some cases, state data elements that did not directly map into the Oracle database were inserted into a comment field within the database. Also, INDUS maintained an internal record of which state data elements were inserted into the comment field.

As part of the data clean-up efforts, INDUS determined whether or not there were any duplicate records in the state data sets and deleted the duplicate records. INDUS checked the waterbody, station, and sample entities for duplicate records. However, if there was not enough information provided to determine duplicates such as sampling date, there was no way for INDUS to locate duplicate records. In addition, INDUS deleted station records with no samples and sample records with no results. INDUS also deleted waterbody records that were not associated with a station. In each case, INDUS maintained an internal record of how many records were deleted.

If INDUS encountered referential integrity errors, such as samples that referred to stations that did not exist, or if INDUS was unsure of whether a record was a duplicate, INDUS contacted the agency directly via e-mail or phone to resolve any issues that arose. INDUS saved an electronic copy of each e-mail correspondence with the states to ensure that a record of the decision was maintained.

Finally, INDUS examined the remark codes of each result record in the state data sets. INDUS mapped the remark codes to the STORET remark codes listed in Table 2 of Appendix A. If any of the state result records were associated with remark codes marked as “Delete” in Table 2 of Appendix A, the result records were not converted into the database.

### **2.3 Laboratory Methods**

Many of the state data sets did not contain laboratory method information. In addition, laboratory method information was not available for the three national data sets. In order to determine missing laboratory method information, EPA tasked another contractor to contact the data owners to obtain the laboratory method. In some cases, the data owners responded and the laboratory methods were added to the database. In other cases, the methods are unknown.

### **2.4 Waterbody Name and Class Information**

A large percentage of the data did not have waterbody-specific information. The only waterbody information contained in the three national data sets was the waterbody name, which was embedded in the station ‘location description’ field. Most of the state data sets contained waterbody name information; however, much of the data were duplicated throughout the data sets. Therefore, the waterbody information was cleaned manually. For the three national data sets, the ‘location description’ field was extracted from the station table and moved to a temporary table. The ‘location description’ field was sorted alphabetically. Unique waterbodies were grouped together based on name similarity and whether or not the waterbodies fell within the same county, state, and waterbody type. Finally, the ‘location description’ field was edited to include only waterbody name information, not descriptive information. For example, 110 MILE CREEK AT POMONA DAM OUTFLOW, KS PO-2 was edited to 110 MILE CREEK. Also, if 100 MILE CREEK was listed ten times in New York, but in four different counties, four 100 MILE CREEK waterbody records were created.

Similar steps were taken to eliminate duplicate waterbody records in the state data sets. If a number of records had similar waterbody names and fell within the same state, county, and waterbody type, the records were grouped to create a unique waterbody record.

Most of the waterbody data did not contain depth, surface area, and volume measurements. EPA needed this information to classify waterbody types. EPA attempted to obtain waterbody class information from the states. EPA sent waterbody files to the regional coordinators and requested that certain class information be completed by each state. The state response was poor; therefore, EPA was not able to perform statistical analysis for the waterbody types by class.



## 2.5 Ecoregion Data

Aggregate nutrient ecoregions and Level III ecoregions were added to the database using the station latitude and longitude coordinates, the county centroid, or HUC (Hydrological Unit Code) centroid. If a station was lacking latitude and longitude coordinates and county information, the data were not included in the statistical analysis. Appendix B lists the steps taken to add the two ecoregion types (aggregate and Level III) to the Nutrient Criteria Database. The ecoregion names were pulled from aggregate nutrient ecoregion and Level III ecoregion Geographical Information System (GIS) coverages. In summary, the station latitude and longitude coordinates were used to determine the ecoregion under the following circumstances:

- The latitude and longitude coordinates fell within the county/state listed in the station table.
- The county data were missing.

The county centroid was used to determine the ecoregions under the following circumstances:

- The latitude and longitude coordinates were missing, but the state/county information was available.
- The latitude and longitude coordinates fell outside the county/state/HUC listed in the station table. The county information was assumed to be correct; therefore, the county centroid was used.

The HUC centroid was used to determine the ecoregions under the following circumstances:

- The latitude and longitude coordinates and county were missing, but the HUC information was available.

If the latitude and longitude coordinates fell outside the continental US county coverage file (i.e., the point fell in the ocean or Mexico/Canada), the nearest ecoregion was assigned to the station.

## 3.0 STATISTICAL ANALYSIS REPORTS

Aggregate nutrient ecoregion tables were created by extracting all observations for a specific aggregate nutrient ecoregion from the Nutrient Criteria Database. Then, the data were reduced to create tables containing only the yearly median values. To create these tables, the median value for each waterbody was calculated using all observations for each waterbody by Level III ecoregion, state, county, year, and season. Tables of decade median values were created from the yearly median tables by calculating the median for each waterbody by Level III ecoregion, state, county, decade and season.

The Data Source and the Remark Code reports were created using all observations (all reported values). All the other reports were created from either the yearly median tables or the decade median tables. In other words, the descriptive statistics and regressions were run using the median values for each waterbody and not the individual reported values.

Statistical analyses were performed under the assumption that this data set is a random sample. If this assumption cannot be verified, the observations may or may not be valid. Values below the 1<sup>st</sup> and 99<sup>th</sup> percentile were removed from the Legacy STORET database prior to the creation of the national database. Also, data were treated according to the Legacy STORET remark codes in Appendix A.

The following contains a list of each report and the purpose for creating each report:

- Data Source—Created to provide a count of the amount of data and to identify the source(s).
- Remark Codes—Created to provide a description of the data.
- Median of Each Waterbody by Year—This was an intermediate step performed to obtain a median value for each waterbody to be used in the yearly descriptive statistics reports and the regression models.
- Median of Each Waterbody by Decade—This was an intermediate step performed to obtain a median value for each waterbody to be used in the decade descriptive statistics.
- Descriptive Statistics—Created to provide EPA with the desired statistics for setting criteria levels.
- Regression Models—Created to examine the relationships between biological and nutrient variables.

Note: Separate reports were created for each season.

### **3.1 Data Source Reports**

Data source reports were presented in the following formats:

- The number and percentage of data from each data source were summarized in tables for each aggregate nutrient ecoregion by season and waterbody type.
- The number and percentage of data from each data source were summarized in tables for each aggregate nutrient ecoregion for all seasons and waterbody type.
- The number and percentage of data from each data source were summarized in tables for each Level III ecoregion by season and waterbody type.

The 'Frequency' represents the number of data values from a specific data source for each parameter by data source. The 'Row Pct' represents the percentage of data from a specific data source for each parameter.

### **3.2 Remark Code Reports**

Remark code reports were presented in the following formats:

- The number and percentage of data associated with a particular remark code for each parameter were summarized in tables by Level III ecoregion by decade and season.

- The number and percentage of data associated with a particular remark code for each parameter were summarized in tables by Level III ecoregion by year and season.

The 'Frequency' represents the number of data values corresponding to the remark code in the column. The 'Row Pct' represents the percentage of data that was associated with the remark code in that row.

In the database, remark codes that were entered by the states were mapped to Legacy STORET remark codes. Prior to the analysis, the data were treated according to these remark codes. For example, if the remark code was 'K,' then the reported value was divided by two. Appendix A contains a complete list of Legacy STORET remark codes.

Note: For the reports, a remark code of 'Z' indicates that no remark codes were recorded. It does not correspond to Legacy STORET code 'Z.'

### **3.3 Median of Each Waterbody**

To reduce the data and to ensure heavily sampled waterbodies or years were not over represented in the analysis, median value tables (described above) were created. The yearly median tables and decade median tables were delivered to the EPA in electronic format as csv (comma separated value or comma delimited) files.

### **3.4 Descriptive Statistic Reports**

The number of waterbodies, median, mean, minimum, maximum, 5<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, 95<sup>th</sup> percentiles, standard deviation, standard error, and coefficient of variation were calculated. The tables (described above) containing the decade median values for each waterbody for each parameter were used to create descriptive statistics reports for:

- Level III ecoregions by decade and season
- Aggregate nutrient ecoregions by decade and season

In addition, the tables containing the yearly median values for each waterbody for each parameter were used to create descriptive statistics reports for:

- Level III ecoregions by year and season

### **3.5 Regression Models**

Simple linear regressions using the least squares method were performed to examine the relationships between biological and nutrient variables in lakes and reservoirs, and rivers and streams. Regressions were performed using the yearly median tables. Chlorophyll(s) in micrograms per liter (ug/L), Secchi in meters (m), Dissolved Oxygen in milligrams per liter (mg/L), Turbidity, and pH were the biological variables in these models. Secchi data were used in the lake and reservoir models, and Turbidity data were used in the river and stream models.

The nutrient variables in these models include: Total Phosphorus in ug/L, Total Nitrogen in mg/L, Total Kjeldahl Nitrogen in mg/L, and Nitrate and Nitrite in mg/L.

#### **4.0 TIME PERIOD**

Data collected from January 1990 to December 2000 were used in the statistical analysis reports. To capture seasonal differences, the data were classified as follows:

- Aggregate nutrient ecoregions: 6, 7, and 8
  - 1.05 Spring: April to May
  - 1.6 Summer: June to August
  - ★ Fall: September to October
  - ★ Winter: November to March
- Aggregate nutrient ecoregions: 1, 2, 3, 4, 5, 9, 10, 11, 12, 13, and 14
  - Spring: March to May
  - Summer: June to August
  - Fall: September to November
  - Winter: December to February

#### **5.0 DATA SOURCES AND PARAMETERS FOR THE AGGREGATE NUTRIENT ECOREGIONS**

This section provides information for the nutrient aggregate ecoregions that were analyzed by waterbody type. Each section lists the data sources for the aggregate nutrient ecoregion including: 1) the data sources, 2) the parameters included in the analysis, and 3) the Level III ecoregions within the aggregate nutrient ecoregions.

Note: For analysis purposes, data for the following parameters were grouped together and reported under Phosphorous, Dissolved Inorganic (DIP):

Phosphorus, Dissolved Inorganic (DIP)  
Phosphorus, Dissolved (DP)  
Phosphorus, Dissolved Reactive (DRP)  
Orthophosphate, dissolved, mg/L as P  
Orthophosphate (OPO4\_PO4)

## **5.1 Lakes and Reservoirs**

### **5.1.1 Aggregate Nutrient Ecoregion 1**

#### Data Sources:

Legacy STORET  
EPA Region 10

#### Parameters:

Chlorophyll A, Fluorometric, corrected (ug/L)  
Dissolved Oxygen (DO) (mg/L)  
Nitrite and Nitrate, (NO<sub>2</sub>+NO<sub>3</sub>) (mg/L)  
Nitrogen, Total Kjeldhal (TKN) (mg/L)  
Phosphorus, Total (TP) (ug/L)  
SECCHI (m)  
pH

#### Level III ecoregions:

3

### **5.1.2 Aggregate Nutrient Ecoregion 10**

#### Data Sources:

Legacy STORET

#### Parameters:

Chlorophyll A, Fluorometric, corrected (µg/L)  
Chlorophyll A, Phytoplankton, spectrophotometric Acid (ug/L)  
Chlorophyll A, Trichromatic, uncorrected (ug/L)  
Dissolved Oxygen (DO) (mg/L)  
Nitrite and Nitrate, (NO<sub>2</sub>+NO<sub>3</sub>) (mg/L)  
Nitrogen, Total (TN) (mg/L)  
Nitrogen, Total Kjeldhal (TKN) (mg/L)  
Phosphorus, Total (TP) (ug/L)  
SECCHI (m)

#### Level III ecoregions:

34, 73

## **5.2 Rivers and Streams**

### **5.2.1 Aggregate Nutrient Ecoregion 13**

#### Data sources:

Florida  
Legacy STORET  
NASQAN

#### Parameters:

Chlorophyll A, Phytoplankton, spectrophotometric Acid (ug/L)  
Dissolved Inorganic Phosphorus (DIP) (ug/L)  
Dissolved Oxygen (% Saturated)  
Dissolved Oxygen (DO) (mg/L)  
Nitrite and Nitrate, (NO<sub>2</sub>+NO<sub>3</sub>) (mg/L)  
Nitrogen, Total (TN) (mg/L)  
Nitrogen, Total Kjeldhal (TKN) (mg/L)  
Phosphorus, Total (TP) (ug/L)  
Phosphorus, orthophosphate, total, as P(ug/L)  
Turbidity (FTU)  
Turbidity (NTU)  
Turbidity (JCU)  
pH